HUMAN HEART MODELING

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A final year project, submitted as a partial requirement for the degree

BACHELOR OF COMPUTER SCIENCE

Faculty of Computer Science and Information Technology

UNIVERSITY OF MALAYA

Kuala Lumpur

2003/2004

ACKNOWLEDGEMENTS

First of all, I would like to take this opportunity to express my heartiest gratitude to my project supervisor, Mr. Woo Chaw Seng for his guidance, ideas encouragement and patience, constructive advice and dedicated assistance throughout the whole course of the thesis project.

I would also like to convey my sincere thanks to my project moderator, Pn. Siti Soraya for her invaluable advice and comments during the project. I would like to take this opportunity to forward my appreciation to the lab assistant and the other staffs for their help and invaluable suggestion during the project.

My sincere appreciation and thanks to the contributions, patience, ideas and understanding of my thesis project partner, Mr. Mohd Tharmezy Md. Tajuddin throughout the thesis project.

The morale support by the Department of Artificial Intelligent, Faculty of Science Computer and Information Technology, University Malaya must be recognized here, as the entire project would not have been accomplished and succeeded without requirements.

Lastly, I would also like to acknowledge the assistance of fellow course-mates and other people who have either directly or indirectly participated in this project. This project can only become a reality with the effort, assistance and cooperation of many individuals whom I sincerely appreciates.

ABSTRACT

Medical imaging technology plays an important role in providing efficient, reliable medical services. In today's technology, most imaging modalities provide individual 2D images for study. However, when internal visualization is necessary, 2D images will not provide medical professionals with complete and precise data, which is important in planning surgeries. If 3D volume images of the anatomy being studied can be viewed, the user will be able to get an accurate view and understanding of the problem.

This project intends to construct a human heart modeling for the purpose of volume visualization. The volumetric data will be first obtained through a series of data conversions and read into the system. Next it will be projected in a 3D view. The system will allow the user to select a cutting image and interactively slice the volume image, where the user chooses. This will allow internal visualization of the volume.

This system will contribute in aiding medical professionals in simulation and planning of difficult surgeries, and can be used for educational purposes as well.

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Chapter 1
Introduction

CHAPTER 1 - INTRODUCTION

HUMAN HEART MODELLING

1.1 Project definition

Human Heart

Human Heart Modelling is a concept to search information about human heart where the main advantage of it is it gives a time domain of pumping of the human heart. The heart is one of the most important organs in the entire human body. It is really nothing more than a pump, composed of muscle which pumps blood throughout the body. The heart pumps the blood, which carries all the vital materials which help the bodies function and removes the waste products that didn't need [19].

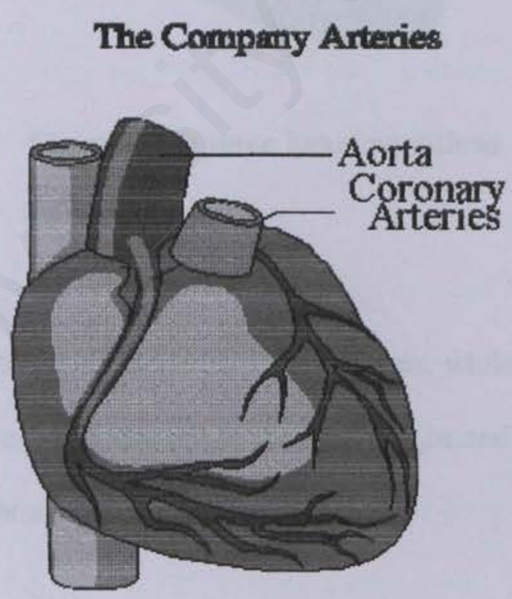


Figure 1.1 The company Arteries

The heart is essentially a muscle like any other muscle in the human body, it contracts and expands. The pumping of the heart is called the *Cardiac Cycle*.

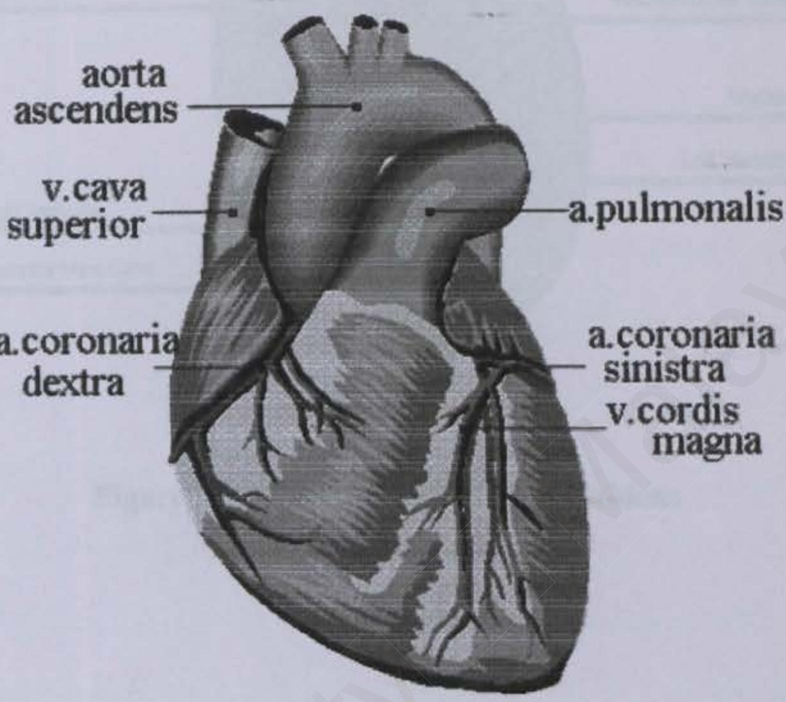


Figure 1.2 Human heart partitions

The walls of the heart are made up of three layers, while the cavity is divided into four parts. There are two upper chambers, called the right and left *atria*, and two lower chambers, called the right and left *ventricles*.

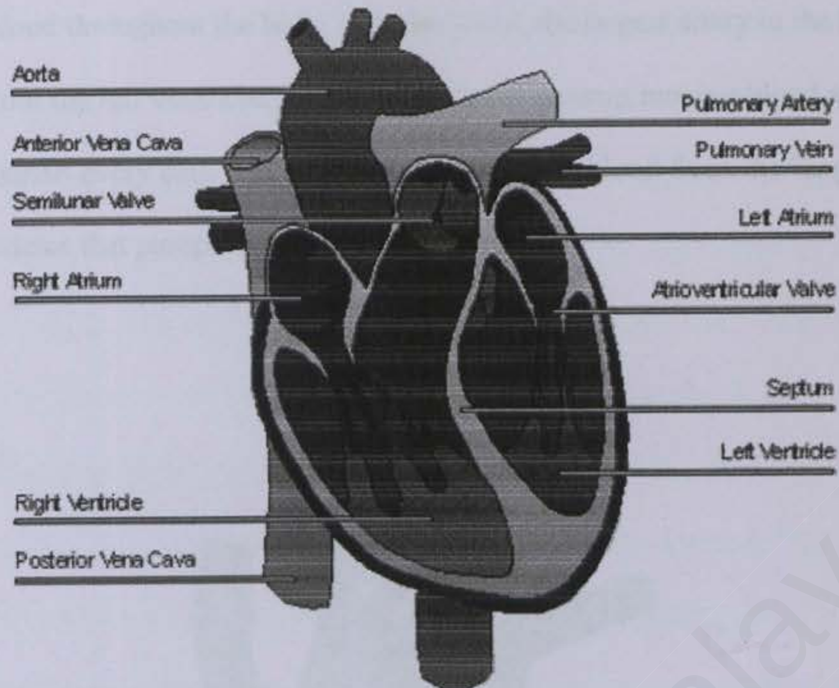


Figure 1.3 Internal human heart partitions

The Right Atrium receives blood from the upper and lower body through the *superior vena cava* and the *inferior vena cava*, and from the heart muscle itself through the *coronary sinus*. The right atrium is the larger of the two atria, having very thin walls. The right atrium opens into the right ventricle through the *right atrioventicular valve*(tricuspid), which only allows the blood to flow from the atria into the ventricle, but not in the reverse direction. The right ventricle pumps the blood to the lungs to be reoxygenated. The left atrium receives blood from the lungs via the four *pulmonary veins*. It is smaller than the right atrium, but has thicker walls. The valve between the left atrium and the left ventricle, the *left atrioventicular valve*(bicuspid), is smaller than the tricuspid. It opens into the left ventricle and again is a one way valve. The left ventricle pumps the blood throughout the body. It is the *Aorta*, the largest artery in the body, which originates from the left ventricle. The heart works as a pump moving blood around in the bodies to nourish every cell. It is the atria that draw the blood from the lungs and body, and the ventricles that pump it to the lungs and body [19].

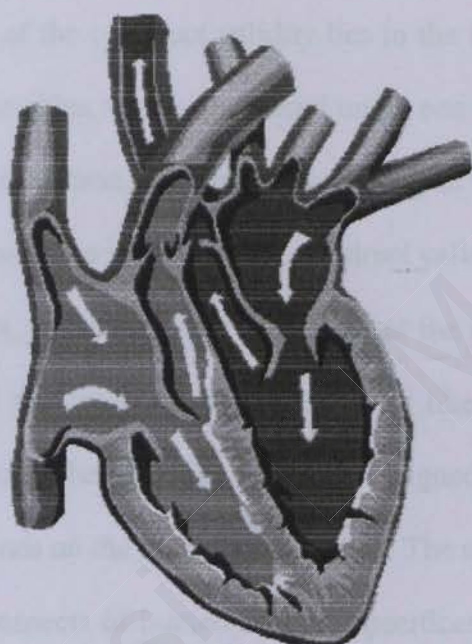


Figure 1.4 The blood flow in human heart

MODELLING

It may be useful to begin with a definition of a model. Models represent an abstraction of reality - it represents what things were like, what it could be like, or what it should be like. Models are designed to clarify certain aspects of a problem or problem area that supposed to highlight certain important relationships and certain key interactions. A well-defined model, in abstracting the essence of the model should clarify it, facilitate analysis of the constraints and potentials, and indicate some of the information needed. A more general definition of a model is a subset of relationships in the real world. Since the subset does not represent all of reality, the validity of the model is limited. There are two types of validity, content validity and construct validity. The former measures the predictive validity of the model, while the latter measures the stability of the construct. Many authors consider only the content validity of a model. However, the importance of the construct validity lies in the fact that any construct is a collection of individual variables, which are placed under one heading. The relationships of these variables change over time, and hence the validity of the construct changes over time. An example might make the importance of construct validity clearer [21].

In this title contact, the model refer to heart that the abstraction from reality of human heart. This model represents what the heart was like, what the heart could be like, or what the heart should be like. The model is designed to clarify the problem in medical purpose that depends on the human heart aspect. The model that wants to build is supposed to show whole aspects of human heart in specification dimension and human heart cycle that include time element. That means the model is design in 3D and adding another one dimension, is time dimension [21].

1.2 Project Objective

The objectives are:

- **Convert 2D images to 3D images**
- **Segment an image**
- **Insert the time domain beside the 3-dimensional heart**
- **Show the pumping of heart in computer graphic**
- **Read in 4 dimensional data, then use AI method to model it**

In order to follow this objective, the modeling process must be at firstly determining the application that useful or available in modeling job. There are several kinds of computer's software application that useful in order to modeling the human heart. Nevertheless this computer application must be according or including the artificial intelligence (AI) technique that showing this modeling are differences from other modeling. The AI technique that will use in this system is fuzzy logic that is used in image segmentation (explained in chapter 5).

1.3 Project Scope

The system can use by any person to learn about human heart.

- **Surgery doctor**

  Use the system to slice the heart into a small part to determine which part of heart have a problem and identified the distance of heart that need to operate.

- **Medical student (university)**

  Use the system to learn and to know about each part of heart by slicing the heart and cut one of it to know the deep and distance they can make a cutting of the heart.

- **Student (school)**

  Use the system to learn and to know about the part of the heart and it function like how blood move from the body into the right atrium, right ventricle, left atrium and left ventricle in human heart.

1.4 Project Activity Plan

To make sure the project that have been develop get the objective in the fixed time, a schedule have been construct. The schedule makes sure the application development process execute in the smooth way. It has six main processes in the project schedule:

i. Project Title and Plan Suggestion

What must to do in this level is to identify the title of the project that construct and the planning for the project. It is include objective of the project, scope and the list for the project performance planning.

ii. Literature Review

In this part, the thing like technology and software that involve in this project will elaborate to the specific. Reference is use through the internet, library, discuss with supervisor and friends, and through the previous student research.

iii. Requirement Analysis

Information like functions that will use for the system will recognize in this level. Through this information, methodology that will use to construct the system will determine.

iv. System Design

In this level, the case that relevant in system design will execute like input and output design for the system.

v. Encoding

The code that will use in the system will recognize in this level.

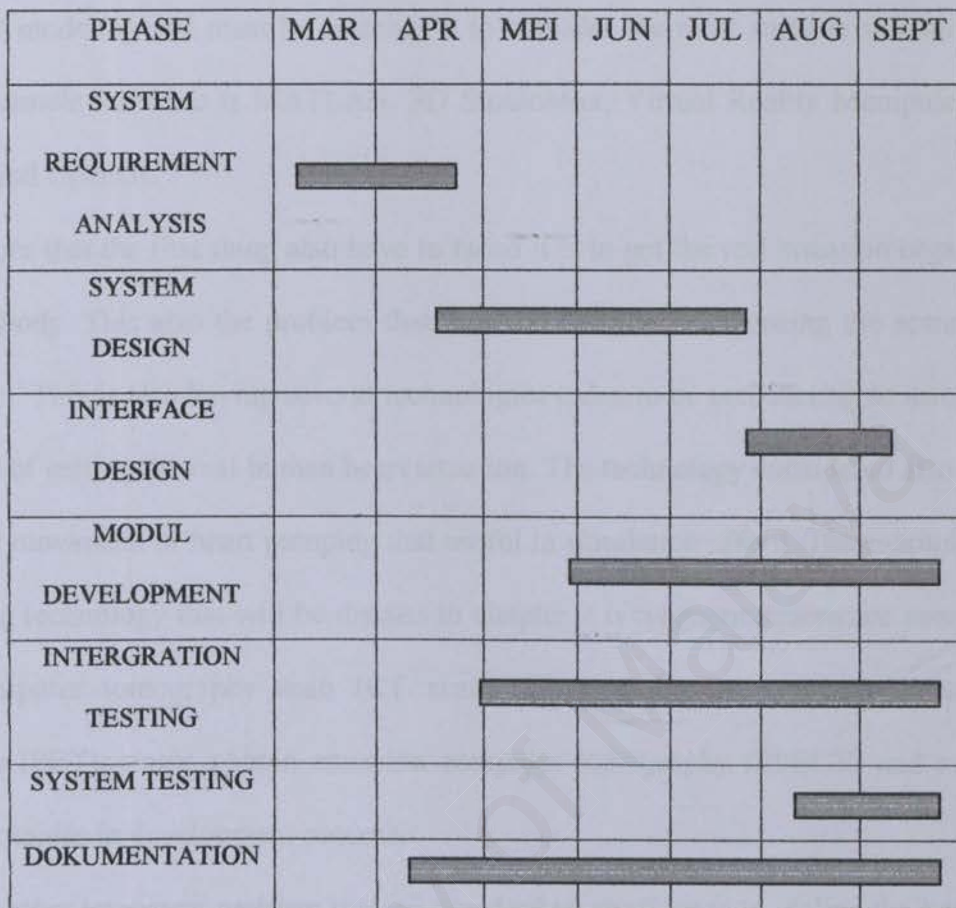
vi. Testing

Testing procedure will execute in this level start from testing at modul level, and then intergration one modul with another modul and testing to all part of the system.

vii. Documentation

The manual will construct in this period, it is important if something error happen or the system modifying in the future. Documentation is important to be the reference for the other constructors to construct their system or to make the system become better.

Figure 1.5 Project schedule



1.5 Problem Domain Analysis

There are several problems when we say to model the human organ in the body. That is to get the real situation human organ before do the modeling process (in this title is human heart). Human heart is the organ that have the biological function and this organ also have the internal movement or pumping. When thinking to model this organ, the problem that we say the major problem to consider is the time domain that modeling is not only models the human heart in 3 dimensional but includes other one dimension (time dimension). This is the problem that we faced when comparing this modeling to other organ modeling in the body. But there are several software in market to perform the 4 dimensional modeling and must be searches it to consider the most suitable software to use. The example software is MATLAB, 3D StudioMax, Virtual Reality Manipulating Language, and OpenGL.

Before that the first thing also have to faced it is to get the real situation organ in the human body. This also the problem that must be consider to choosing the scanning technologies. This is also having several technologies today to be considering to using in the purpose of getting the real human heart situation. The technology considered also can perform the movement or heart pumping that useful in simulation afford. The example of the scanning technology that will be discuss in chapter 2 is magnetic resonance imaging (MRI), computer tomography scan (CT scan), Ultrasonography, positron emission tomography (PET), single photon emission computer tomography (SPECT) and many more technologies in development process.

The other important problem that we faced when consider to modeling the human heart in the independent of scanning material format to the manipulating software format. When using the software for modeling process the format for input material from scanning afford must be converted to available format in the modeling software. This is the thing and the problem between the performances for integrating in modeling software and the available scanning format choose.

Chapter 2
Literature Review

CHAPTER 2 - LITERATURE REVIEW

2.1 Introduction

Literature review is the research to collect all information about the Human Heart Modelling that is needed to construct the system. The collection is doing to all thing to construct so that will be guidance to make a plan in the application development process. To get the best result or value of a project that can give what the requirement and needed of the team like developer, client and user. The variety form of research must do the best way by the system development. If something small error happen, maybe it can give a big problem effect from the error and difficult to solve the problem. That is some main factor of literature review which research of background to take an update and new information about specific aspects that in around the project. The result from the research can used for variety of case, as an system development is important to understand the definition, objective, requirement, and the relevant issues before the developer develop the best of quality of system.

The specific research is progress to the web equipment and it's technology and the system environment too. System environment research is the research about the existed problem happen factors when execute the system from the technique understanding and codes involve explanation for get into the system human heart modelling.

The easy way to explain the literature review is progress for completes some objective like:

i. For get some information about system that is develops by developer.

ii. To study and assess the system that have the same and relevant concept, that have been develop to determine the weakness and the strangeness of the system and improve the weakness of the system that has been identified.

iii. To get the clear understanding about concepts that involve in the system that will develop and compare the software with another software that will use to get the best product and solving.

The information is search from:

- **Information from internet source**

  This is the main source, it is easy and quick to get information about human heart modelling. The way to search the reference of the human heart is using search engine like Yahoo, Google and Altavista.

- **Library**

  Refer to the text books, journals, news paper, magazine and the other information about human heart to construct this application.

- **Doctor**

  Meet with a doctor to know what they need and a view for the doctor when they make an operation, what information they want to know before an operation begin.

2.2 Magnetic Resonance Imaging

2.2.1 What is Magnetic Resonance Imaging

Magnetic Resonance Imaging (MRI) is a non-invasive medical imaging technique that visualises internal structures, of the particular anatomy of a living organism. It produces high quality images of internal organs or tissue structures. MRI is based on the principles of nuclear magnetic resonance (NMR). NMR is a spectroscopic technique used by scientists to obtain microscopic chemical and physical information about molecules. This technique was renamed as magnetic resonance imaging, because of negative connotations associated with the word nuclear in the late 1970's [2]. MRI technology was first developed as a tomography of 2D imaging technique that produced an image of the NMR signal as a thin slice through the human body. The technology has now advanced to a volume or 3D imaging technique [2].

2.2.2 Various Medical Imaging Techniques

The popular medical imaging techniques of today are X-ray, computed tomography (CT), MRI, NMR, ultrasonic waves and positron emission tomography (PET) [1]. Medical imaging technologies are based on various physical phenomenon, such as radiant energy emission in X-rays, X-ray attenuation in CT, relaxation of magnetized hydrogen nuclei in MRI, and radioactive decay of particles in PET [1].

X-ray was discovered by German physicist Wilhelm Roentgen in 1895. It is form of radiant energy that is used in the diagnosis and treatment of certain diseases. X-ray images have little contrast and do not provide information about the specific of an object.

However it gives excellent bone rendition, making it an effective technique for detecting fractures, X-rays give only one view of the human anatomy but it is very often large molecules such a calcium, absorb the rays and partially occlude the organs behind them [3][4].

Medical images taken of the human body are acquired or displayed in three main orientations:

1. Coronal orientation: in a cross section (plane), for example, across the shoulders, dividing the body into front and back halves
2. Sagittal orientation: in a cross section (plane), for example, down the middle, dividing the body into left and right halves
3. Axial orientation: in a cross section (plane), perpendicular to the long axis of the body, dividing the body into upper and lower halves

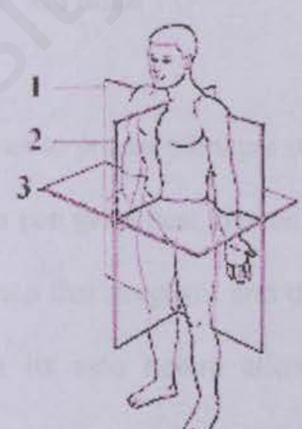


Figure 2.1 Three main orientations of human body

CT is especially suitable for imaging high density objects such as bone. In a CT scanner, an X-ray machine rotates around the patient, bombarding the patient with thin, fan-shaped X-ray beams. The beams are recorded on sensitive detectors on the opposite side of their source. The scan rotates the X-ray beam at 180 degrees, thus producing many images of the same organ and an internal cross-section of the anatomy [1][4].

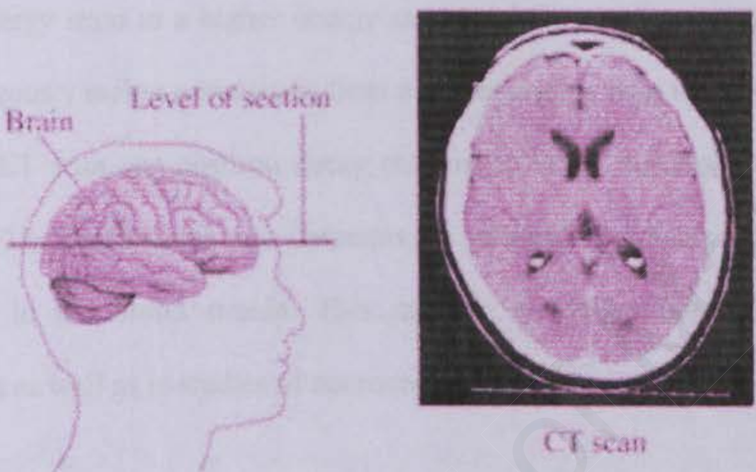


Figure 2.2 CT scan

The ultrasound uses sound waves to produce images of the organs and soft tissues like blood vessels in the arms and legs can get a best viewed with ultrasonic waves. It is an ideal technique for looking at woman that pregnant and their child inside because no ionizing radiation is used. Although its safe nature allows routine scans, the long wavelength was applied that limits the ultimate resolution [1][3].

In the MRI technique, the body is surrounded by very powerful electromagnets that can detect the nuclei of hydrogen atoms that can found in water. It is possible to infer changing the densities of hydrogen atoms and their interaction with tissues. An obtain images are recorded from the signals of radio-frequency that represent a difference in time to rest of tissue nuclei in an electromagnetic field. MRI is used for diagnostic and research purposes [4][5]. NMR imaging is used to help MRI in some cases because MRI is based on the principles of NMR. NMR is a spectroscopy based on the spin of the nucleus of an atom. The signal is produced in NMR spectroscopy results from the difference between the energy absorbed by the spins which makes a transition from a lower energy state to a higher energy state, and the energy emitted by the spins which simultaneously makes a transition from a higher energy state to a lower energy state [2].

PET scan use positron decay patterns to study metabolic reactions in the body system [3]. These scans use detectors or radioactive tracers to measure radioactive particles in the blood stream. This imaging technique has been useful in medical diagnosis as well as in studies of neurocognition [4].

2.2.3 The discovery of MRI

Bloch and Purcell, discovered the magnetic resonance phenomenon independently in 1946 [2]. In the period between 1950 and 1970, NMR was developed and used for chemical and physical molecular analysis. In 1972, the X-ray based computerized tomography was introduced. This date is important to the MRI timeline because it showed hospitals were willing to spend a large amount of money for medical imaging hardware. In 1973, Lauterbur demonstrated imaging using NMR and in the CT using the back projection technique. In 1975, Ernst proposed magnetic resonance imaging using phase and frequency encoding that is the current MRI technique. Edelstein and coworkers demonstrated imaging of the body using this technique in 1980. A single image could be acquired in approximately five minutes. By 1986, the imaging time was reduced to about five seconds without sacrificing to much on image quality [2].

In 1988, Dumoulin introduce MRI angiography, which allowed imaging of blood flow without use contrast agents. In 1989, echo-planner imaging was introduced which image acquisition is a high speed rates. Many clinicians thought this technique would be applied in dynamic MRI of joints, instead it has been used for imaging the regions of the brain responsible for thought and motor control. In 1991, Richard Ernst was rewarded for his achievements in pulsed NMR and MRI with the Nobel Prize in Chemistry. In 1994, researchers at the State University of New York at Stony Brook and Princeton University demonstrated the imaging of hyperpolarized 129Xe gas for respiration studies [2].

For more than a decade now, physicians have used MRI to produce accurate representations of internal and external anatomical structures. With the help of these images, abnormalities such as tumours can be easily detected. Today, MRI data are being used not only by physicians, but also medical device manufacturers. Through the use of 3D models derived from MRI data, medical devices such as implants or prostheses can be designed to accurately conform to the shape of the human body [6].

2.2.4 The principle of MRI

In an MRI examination, the patient is placed in a strong electromagnetic field. When this happens, the millions of hydrogen atoms in the body align themselves parallel with the magnetic field, either in the same direction or opposite to the direction of the field. At the level of slice where it is determine to take a picture, a short powerful radio signal is sent through the patient's body. The hydrogen atoms that have the same frequency as the radio wave, will move and that will be raised to a higher state of energy and start to resonate with the exciting wave.

When the radio signal is turned off, the hydrogen atoms will return to their original energy state after a period of time. The excitation energy that had gained will be released in the form of radio waves that are detected by the MRI machine. The time it takes for the excited hydrogen atoms to return to their original energy level depends on the number of atoms and characteristic physical of the various tissue types. This time is measured and analysed by a computer, which on the basis of these measurements constructs an image of the tissues within the body.

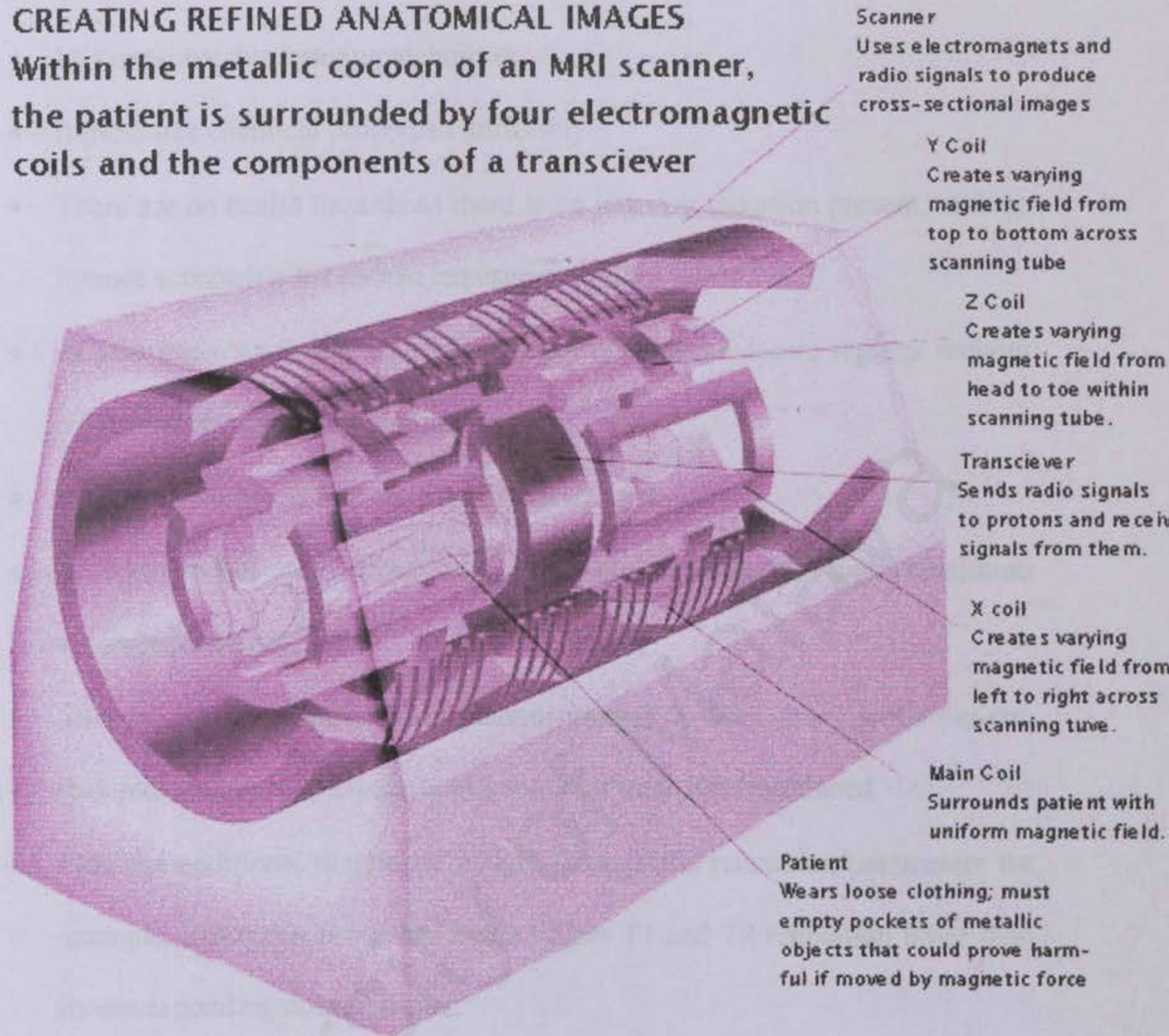


Figure 2.3 Magnetic Resonance Imaging

2.2.5 The advantages of MRI

MRI scanning has many good features that make it an advanced, efficient and non-harmful medical imaging technique. These features also make it a suitable imaging modality for research in the volume visualisation field.

The advantages are as follows [3][9]:-

- It is non-invasive imaging technique.
- It measures chemical properties uniformly.
- There are no health hazards as there is no ionizing radiation present, making it more acceptable for human experimentation.
- It also provides nearly isotropic images of large anatomic regions without exposing the patient to radiation.
- It can image objects that are transparent to light.
- It distinguishes soft tissue well, providing reasonably high resolution volumetric images.
- MRI is able to produce multi-planner images without moving the patient, thus reducing motion artefacts and degradation in slice produced.
- Provides additional diagnostic insight through the relaxation parameters for example, cancerous tissue has much higher T1 and T2 relaxation times than its corresponding normal tissue.
- Its short examination time reduces patient discomfort.
- MR images are readily available for use.

2.2.6 The weakness of MRI

Just as MRI has its numerous advantages, a few weakness of MRI with relation to patient safety and imaging problems are:-

- High cost

  Because of extremely high costs of equipment and medical, expertise needed, this technology is not very widely used at the moment.

- Extremely strong magnetic field

  The strong magnetic field in which the patient is laid can cause certain types of medical implants to be ripped out the patient, as it is drawn to the magnetic field, thus endangering the patient.

- Referencing problem

  The human anatomy is curved in nature, and offers no fixed referencing point from which scans can be taken. There is also the possibility of the patient moving while scanning is being done. Therefore scans taken are sometimes inconsistent in terms of distance and exact position, causing problems during alignment for volume visualisation.

2.3 Project Related Areas

2.3.1 Computer Imaging

Visual information that transmitted in the form of digital images is becoming a major method of communication in the modern situation. Computer imaging can be defined as the acquisition and processing of visual information by the computer. The importance of computer imaging is derived from the fact of visual sense and the information that can be conveyed in the images is extraordinary [7].

Computer representation of an image requires an amount of data without the medium used to represent the image would be inefficient. The massive amount of data required for images is one of the reasons for development of many sub-areas within the field of computer imaging, image compression and segmentation. The receiver of the visual information and the human visual system or the computer itself provides another important aspect of computer imaging [7].

The field of computer imaging can be divided into two major categories:-

i) Computer vision

ii) Image processing

In computer vision applications, processed images are for use by a computer. In image processing, processed images are for human consumption. The human visual system, and the computer as a vision system, have various limitations and strengths. Computer imaging researchers need to be aware of the functionality of these two different systems. The field of image processing grew from electrical engineering as an extension of signal processing. Computer vision developed from the area of computer science. Computer imaging combined the techniques of computer vision and image processing [7].

2.3.2 Computer Graphics

Computer graphics is a specialized field within the real of computer science that refers to producing of visual data through the use of the computer. This includes the creation of computer images for display and the process of generating or manipulating any images for output. Computer graphics provides methods to synthesize images from numerical descriptions. These techniques were originally developed for realistic displays of human-defined objects such as a models from computer aided design (CAD). Objects in 3D space are usually represented by infinitely thin surface patches such as triangles or higher order curves. Contributions or computer graphics to 3D imaging include data structures, projection techniques and shadowing models [1][7][8].

A major use of computer graphics is in design processes. Computer aided design (CAD) methods are used in designing. When object designs are complete or nearly complete, realistic lighting models and surface rendering are applied to produce displays that will show the appearance of the final product [8].

Image processing and computer graphics are typically combined in applications of medical. These techniques are used to model and study physical functions, design artificial limbs and plan, and practise surgery. 2D cross section of the body are obtained using imaging techniques. These slices are then viewed and manipulated using graphics methods to simulate actual surgical procedures and to try out different surgical cuts [8].

2.4 Visualisation

2.4.1 Overview

Scientists, engineers, medical personnel, business analysts, and others often need to analyse large amounts of information or to study the behaviour of certain processes. Numerical simulations carried out on supercomputers frequently produce data files containing millions data values. Similarly, satellite cameras and other resources is a large data files that faster than it can be interpreted. To scan these large sets of numbers to determine the relationships is an ineffective process. But if the data are converted to a visual form, the patterns are often immediately clear. To produce graphical representations for scientific, engineering and medical data sets and processes is generally referred to as scientific visualisation [8][15].

There are many different kinds of data sets, and an effective visualisation depend on the characteristics of the data. A collection of data can contain scalar values, vectors, high-order tensors, or any combination of these data types and data sets can be 2D or 3D and the colour is just one way to visualise a data set.

Other techniques in the visualisation is like contour plots, graphs and charts surface renderings, and visualisations of volume interiors. Image processing techniques are combined with computer graphics to produce many of the data visualisation [8].

The visualisation of the volumetric data has aided many scientific disciplines ranging from biomedical sciences to distance learning to geophysics. The diversity of the fields and the growing reliance on visualisation has led to its importance. There is so much emphasis on visualisation as it is often the most intuitive mode of analysis.

Currently a lot of research is being done for implementing specialised visualisation systems [8][15].

Visualisation need an information from a 3-dimensional data. It is the process of creating images from data in order to assist comprehension. It is an essential tool for many scientists who work in large 3D data sets. These data sets are usually too large to comprehend by examining individual data values. The speed and memory capacity to handle the data sets and to generate images at interactive rates should be very high. Much of the research is being concentrated in creating visualisation algorithms, quicker techniques and software for 3-dimensional data sets [8][15].

2.4.2 Volume visualization techniques

2.4.2.1 Direct surface rendering

Surface rendering is an image visualisation process that displays the external border side of an image rather than slices through the volume. Volume rendering preserves all the information about the slices so that we can see not only what the surface look like, but also what is inside. Surface rendering work only for the surfaces themselves and the inside is not visible. Volume rendering incorporates more information, but is more difficult to achieve (especially to hardware and software requirements). In some cases, it is needed to display both the internal image information as well as the surface [15][16].

2.4.2.2 Direct surface rendering and shadows

This is an image visualisation process that displays the exterior boundary of an image and incorporates the shadows of the object [15][16].

2.4.2.3 Voxelisation

Voxelisation is the process of producing 3D data from an object description like polygonal meshes, so that each voxel has a value. Voxel(volume element) is the name given to a value in 3D space. The data can then be rendered using a volume visualisation technique to produce an image of the original object. Voxelisation is the process of converting an object of one description into volume data. Appropriate volume visualisation techniques can be applied to any data [10][11].

2.4.2.4 Volume rendering

Volume rendering is the process of obtaining images from three dimensional volume data by treating the data. Each value in the data has a colour and opacity assigned to it during a classification stage. Rays are cast for each pixel into the volume, and the colour and opacity are sampled at distributed points along the ray. These samples are composited using standard techniques to produce the accumulative colour and opacity reaching the pixel. Image produced by this method usually have several differently coloured semi-transparent skin overlaid on opaque bone for an image of a CT scan. Volume rendering methods include standard volume rendering method, adaptive termination, no shading, template method, bilinear method, x-ray method, maximum value method, maximum value method with depth cue and Sabella's method [15][16].

One of the most popular algorithms for volume rendering involves generating colour and opacity values for each element in the data set and combining the values along the path of an imaginary ray fired through the data set. These values of colour and opacity are then used to produce the pixel value for the final image. There are three main steps involve in volume rendering [12][13]:-

i) Classification and shading

ii) Ray casting

iii) Splitting

2.4.2.4.1 Classification and shading

The first step of the algorithm involves obtaining a value for the opacity, classification, and the colour. There are two possible methods for this stage. In one isosurfaces are calculated by mapping an opacity to data values with represent boundaries. To avoid introducing artefacts, the data with values near that of a boundary value is assigned an opacity near that of the boundary opacity. In the other method, each material is assigned an opacity, and the linear mapping is used to convert the voxel values into opacities. This ensures that any thin, wispy regions will still appear in the final image. The overall effect of this classification method is to produce a superimposition of multiple semi-transparent surfaces [12][13].

2.4.2.4.2 Ray casting

Once an opacity and colour has been obtained for all the volume elements in the data set, these must be combined to produce a final image. This is usually done by calculating the contribution of each volume element in the path of a ray that fired into the volume in the direction of the final image. At sample points along the ray, the colour and opacity are interpolated from the surrounding values for that points on the ray. The values along the ray are then combined and the final image can be displayed. These volume rendering techniques are all free structure. This makes them more effective than surface rendering for complex scenes as it do not make any assumptions about the presence of features like surfaces in the data.

2.4.2.4.3 Splitting

Another variation on volume rendering is known as splitting. In this case, the voxels in the datasets are traversed from front to back with one slice of voxels, and their individual contribution to the final image and calculated using a filter that known as a reconstruction kernel. The term splitting comes from the analogy with throwing snowballs at a glass plate. The contribution of an individual snowball is higher nearer its centre and gradually tails of towards the edges. This is reflected in splitting in the filter used to calculate the contribution of the voxels to the final images [15][16].

Splitting has similar advantages and disadvantages to the standard volume rendering techniques. However it does have an additional advantage that it is possible for the user to see the image growing one slice at a time, rather than one pixel at a time as with the ray casting technique.

2.4.2.4.4 Development of parallel graphics algorithms

Visualisation is the process of creating images from data in order to assist comprehension. The generation of images that used for visualisation relies a standard graphical techniques like ray-tracing, 2-buffer and alpha-buffer rendering as well as algorithms like volume rendering and isosurface generation which are specifically intended for dealing with 3D data [16].

2.4.2.4.5 Animation

All the methods of displaying volume data that are described above have limitations in that require the volume data to be reduced to 2 dimensional data for display. Another way in which the 3 dimensional of the data can be visualised is by making use of animation [15].

Animation involves moving the image plane in a defined path round the data set. This allows the data to be viewed from slightly different direction each time. If the frames or individual images of the picture, can be viewed quickly enough then the effect of motion parallax will give the image the illusion of 2 dimensions. However, in order to make use of motion parallax with real time visualisation, images must be produced at the rate of at least 10 per seconds and the real time visualisation of volume data sets is still an active area of research [15].

In the meantime, an animation is still a useful tool for understanding volume data by storing the images and looking at the animation although all the images have been produced. An additional advantage to use animation to view volume data is that the individual images do not have to be detailed as the effect of motion parallax that can compensate for some loss of detail in the image [15].

2.4.4 Pre-processing

2.4.4.1 Data conversion

The first step in the image processing pipeline after image acquisition is data conversion. Besides a change of data format, this also involves measures for data reduction to save storage space and processing time. 3D imaging usually works with big amounts of data. A typical CT study of 80 cross-sections with 512 x 512 pixels each, takes 40 megabytes of memory. It an interpolation step is performed, the size of the data may be multiplied common techniques of data reduction like [1]:-

- Cutting

  -A region of interest is chosen , other parts of the image are cut away.

- Reduced spatial resolution

  -The matrix size is reduced, for example, by averaging from 512 x 512 pixels to 256 x 256 pixels.

- Reduced intensity resolution

  -For example, a 16 bit to 8 bit reduction

  -An intensity window is chosen which represents most of the contrast in the images. This is usually done with a histogram, which shows the distribution of the grey values.

The reduced spatial and intensity resolution methods will generally cause some loss of information, therefore these methods must be used with care [1].

2.4.4.2 Filtering

Another important aspect of pre-processing is image filtering. Filtering is a general term for all kinds of image processing routines which are used to make smooth or enhance the information contents of an image. An example is to improve the signal-to-noise ratio, especially in MRI images. Commonly used noise filters are average, median and Gaussian. Unfortunately these filters smooth out small details as well. Better results can be obtained with anisotropic diffusion methods. Other filter types are applied to emphasize special aspects of an image like to enhance edges.

Filters can be designed to work on 1D line, 2D images, 3D volumes, or higher dimensional data. A 1D filter can also be applied to the individual rows or columns of a 2D image. However, results are better if an image is filtered with a 2D filter and a volume with a 3D filter.

2.4.4.3 Data structures

Some of the important data structures used for volume data include:-

- Binary voxel-model

-Voxels values are stored as either 1 (object) or 0 (no object). This simple model is not commonly used anymore. In order to reduce storage requirements, a data structure that is called octree is a hierarchical tree structure, in which binary volumes are recursively subdivided into homogenous sub-volumes, can be used.

- Grey level voxel-model

-Each voxel holds intensity information

- Generalized voxel-model

-Each voxel holds a grey values and information like object membership label, material percentages or data from other sources. This data structure is used for many advanced applications.

2.4.5 Object definition

A grey level volume usually represents a large number of different regions. Which part of the volume or which voxels, constitute which region of the image To display a particular region of interest, must be identified. This information is also needed for morphometric measurements of distances, angles, and volumes. Object definition involves the establishing of between voxels and meaningful anatomical terms. This task is performed through segmentation and interpretation.

2.4.5.1 Segmentation

This process involves partitioning the grey level volume into different regions which are homogenous with some formal criteria while corresponding to real anatomical objects. An example of segmentation is specifying an intensity range with lower and upper threshold values. A voxel will belong to the selected class only if its intensity value falls in the specified range [1].

Thresholding is a method commonly used to select bone or soft tissue in CT. It is often performed during the rendering process so that no explicit segmentation step is required. A drawback of this sort of method, is that a small objects with cover only a small fraction of a voxel and some of cases cannot be handled efficiently. To model the cases, fuzzy segmentation techniques have been developed, whereby a set of probabilities is assigned to every voxel, indicating the evidence for different materials [1].

2.4.5.2 Interpretation

Interpretation is a step in which various regions of an image are identified and labelled with meaningful terms such as white matter or ventricle. This process can be performed interactively or with an automatic system [1].

2.5 Slicing

Slicing is a volume visualisation method that has been used in medicine for a long time. Every CT or MRI scan can slice of the total volume dataset of a human. Radiologist use different slices to reconstruct the 3D volume [17]. In slicing a two-dimensional plane, or slice, it is extracted from the three-dimensional data cube and displayed as a two-dimensional image. The slice may be either parallel to one of the axes of the cube or at an arbitrary orientation. The slice will show detailed information about the plane that has been displayed and didn't give an impression of the centre cube.

In principle, slicing renders a slice of arbitrary orientation from a 3D dataset. To obtain a 3D idea of a volume dataset, slices can be rendered separately and viewed after each other. If a dataset contains voxels with a number in the order of n^3, the sliced image contains voxels with a number in the order of only n^2. Therefore, only n^2 voxels have to be sampled to calculate the final image. This means that slicing is fast, because it generates a 2D image from a 3D dataset [17].

The slices or planes can have different orientation:-

1. Orthogonal

   – This type of slice is easy to sample by taking the slice with the desired x-, y- or z-value.

2. Arbitrary direction

   – This type of slice needs resampling in order to obtain the proper value in the image.

The voxels intersected by the slice have to be rendered. This is known as voxel-mapping. One method of slicing is using multiple slices or planes that often to move through the volume. This method has been found to be conceivable and user-friendly. This method is known as multi-planar re-projection or multi-planar reformatting. The slices that is used to create the image, are most often convex. An implementation of the algorithm to voxel-mapping the slice, is explained below. This algorithm is actually just a 3D-variant of the well-known algorithms for scan-conversion of 2D polygons, based on edge coherence. Slicing or multi-planar reformatting can also be combined with other visualisation methods.

Assuming the projection area of the 3D polygon (the plane) on the XY plane is the largest and the voxel-mapping algorithm works as follows:-

1. Sort the vertices of the plane with increasing Y.
2. Sweep from Y min to Y max: at vertices, update active edges, between vertices, compute where the current Y-value intersects the plane (using dz/dy, dx/dy values).
3. Scan convert the voxels on the span, intersecting the Y-value with the plane produces the line segment.

This method is simple to implement. It is so fast and the real time display with manipulation of planes in volume data is possible. However, it doesn't show the whole volume and therefore is not as informative as other volume rendering methods.

Another simple and effective method of visualising the entire cube is to generate an animation that show a sequence of slices being swept through the cube parallel to one of the axes. The slice should be shown in perspective, in its correct position inside the cube. The slice must show with a wire grid or set of axes to show the extent of the cube. The user should be able to control the speed of the animation, select individual frames for inspection or change the colour table. An animation of this sort is the simplest method of displaying an entire data cube and can give good results.

2.6 Obtaining volumetric data

3D image are made up of voxels or volume elements. The voxels is a three-dimensional analog of the pixel. A voxel has a position that uniquely identifies it's location in space. This position is specified as an (x,y,z) coordinate triplet and represents a value [10][11].

Three dimensional volumes are broken into smaller square elements, it can be divided into discrete, cubic, unit elements for storage in memory. Each voxel is a cubic base unit of space containing a value and usually representing colour. If broken down, or voxelized and stored in a suitable data structure, a 3D object can be displayed detail in linear time, independent of complexity of the object, and depend on the number of voxels used to represent it [10][11].

A volume is simply a 3D array of data. The type of data can be anything and required information can also be pre-computed and stored in a voxel. Typically a voxel is made up of three field as shown in Figure 2.7 below.

Scalar	Normal	Gradient

Figure 2.4 Fields in a voxel

The data stored in the voxel includes an 8-bit scalar value and two pre-computed fields. The scalar value yields volume information, or information needed to create the volume file, and is used for classification. The first pre-computed field is a surface normal vector encoded in a 16-bit field. It gives surface information used for doing shading routines. The second pre-computed is the gradient-magnitude of the scalar value. This field can be used for detecting surface boundaries during classification.

2.7 Ultrasound

Ultrasound utilizes has high-frequency sound waves, which are reflected in specific ways by different tissues, normal or pathological, in the body. Ultrasound is mechanical high frequency longitudinal vibration of molecules, and differs from usual sound only by its frequency. It is not ionising and not harmful at the energy levels that used for diagnostic purposes. The reflected sound (echo) is processed by a computer to produce a real-time image which is displayed on a screen instantly. Ultrasound is used to examine many parts of the body [20].

2.7.1 The principle of ultrasound

The principle for ultrasound, or ultrasonography, is the same for underwater sonar or echo sounding. The ultrasound equipment sends an ultrasonic wave through the body at a speed of about 1,500 meters per second. At the interface between two types of tissue, the wave will be refracted, and part of the wave will be reflected back and detected by the ultrasound equipment. The rest of the ultrasonic wave continues move into the body, and is reflected as an echo from the surface of tissues inside the body. It's reflected depends on the densities of the respective tissues, and thus the speed of the sound wave as it passes through them. The time that taken for the reflected wave to return and determined how deep the tissue lies in the body by obtains a picture of the relative locations of the tissues in the body. Some structures will also absorb the sound waves, so that in the end there is little or nothing left to reflect. In this way, a kind of sound-shadow is formed. Based on these properties, it can create a picture of what the structures inside the body look like [20].

The location of the various structures is calculated based on the speed of sound as it travels through tissue, which in almost all tissues is about 1500 m/s (300 m/s in air). The time a sound wave uses from when it is transmitted, encounters an interface, is reflected and returns to the acoustic source which are both transmits and receives the signals, is divided to back and forth, and multiplied by the velocity. If something produces an echo after 0.0002 seconds has elapsed, then it is located 15 cm inside the body.

Ultrasound examinations are best suited for investigations of soft tissues. Ultrasonic waves move slow through air and bone, and ultrasonography is therefore not suitable for examining organs behind bone structures like the brain within the skull [20].

Blood and other fluids reflect sound waves a little and allow them to pass through more or less thick until encounter the surface of something thicker. For this reason, ultrasound has traditionally been used in examinations of the liver, kidneys, various abdominal organs and also the heart.

2.7.2 Ultrasound of the heart

For heart diagnostics a special type of ultrasound is often used, employing what is known as the Doppler technique. An effect the Doppler technique is a change in frequency that occurs when waves are reflected from something that moves. The sound wave becomes compressed and will produce a higher pitch that same with higher frequency when the reflector is moving towards the observer or acoustic source, and a lower pitch or frequency when the reflector is moving away from the observer. Based on this changing in frequency, the speed and direction of the reflector can be determined. With Doppler-enhanced ultrasound it is also possible to measure the speed and direction of the blood flow [20].

With ordinary ultrasound only can see the difference between the heart muscle and the blood-filled chambers of the heart and also see the heart valves. With Doppler enhancement, it can see how the chambers fill and empty with each heartbeat and whether the valves are leaking, in which case some of the blood will reverse flow and the heart functions efficient less.

2.7.3 Ultrasound Contrast

Ultrasound images can be improved by using a contrast agent, although these are different from those used for X-ray contrast media. With X-rays, the contrast agent's can absorb these rays and determining factor for give good discrimination. An ultrasound contrast agent's task is to increase the refraction and reflection of the ultrasonic waves.

One way of doing this is to use a contrast agent which consists of millions of small air bubbles. Each of the air bubbles will reflect the sound wave. In this development, small gas bubbles with a size of less than 10 μm are stabilised within a biodegradable shell. Without this shell, the bubbles would be stable only for a while, as the unstabilised bubbles would become larger bubbles. Besides being potentially danger to the patient, large bubbles have different and less suitable reflective properties. By filling the blood stream with the ultrasound contrast agent, it is possible to increase the reflections from the blood-filled chambers of the heart, so that their image on the monitor will be clearly differentiated from the heart muscle itself [20].

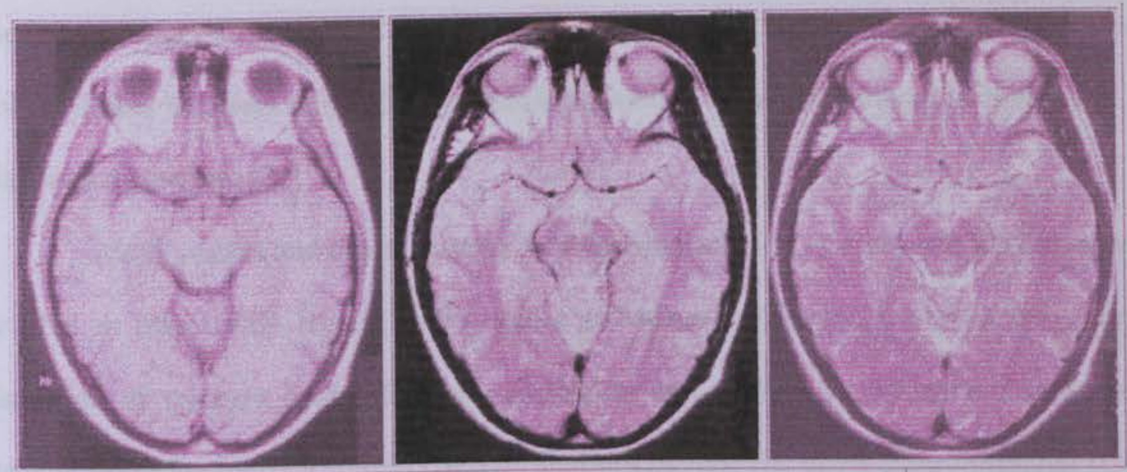


Figure 2.5 Ultrasound Contrast

2.8 Imaging with ionising radiation technique

The oldest imaging technique that still used in the world is X-ray is a ionising radiation, discovered by the German physicist Wilhelm Conrad Röntgen in 1895. In the century since Röntgen's discovery, electromagnetic radiation in the form of *ionising radiation* like gamma and X-rays has been became the energy source for diagnostic radiology.

The basic principle for using X-ray involves and produced by an X-ray tube that passes through the selected parts of the body. Depend on differences absorption in X-rays, the amount of X-rays passing through the different tissues will create an image either on a screen or on an X-ray film. The image that is called a radiograph or X-ray picture, can take several forms. It may be a plain radiograph, like the common skeletal or chest X-ray. A mammogram and an X-ray image of the female breast used to scan for cancerous tumors or a computed tomography (CT) scan, a computer analysis of a crosssectional image of the body. CT has many ways revolutionized medical imaging because of the ability to detect small changes that is not visible with conventional techniques in a fast an safe manner [20].

Many organs and organ systems, and certain muscular or other soft tissue are not visible in detail with routine radiographic techniques. It becomes visible only after injection of contrast media that are substances and opaque to radiation. Diagnostic techniques using inert barium as contrast medium include the upper gastrointestinal (GI) series and barium enema (colon examination).

Iodinated contrast media are excreted by the kidney only a few minutes after injection, this is the basic for urography that is performed to visualise the urinary tract. An injection intravenous contrast media are frequently used during a CT scan to enhance pathological that can found. It can also be used to visualise joints, spinal cord and nerve-roots and vascular tree like angiography, venography and lymphangiography. Contrast media with magnetic properties are used in conjunction with MRI [20].

Another type of diagnostic imaging which uses ionising radiation is radiopharmaceutical imaging also known as nuclear medicine (NM), where small amounts of radioactive material are injected into the body. The radiation doses used in NM are neither larger nor more dangerous than X-rays. Images produced with NM are often not clear as an X-ray and MRI images. However, nuclear imaging is designed to provide information about the function of the body organs and systems whereas X-ray and MRI concentrate mainly on anatomical information [20].

2.9 Medical Imaging

Before the 20th century, the only way of observing disorders of the internal anatomy was to make hole and cut in the patient's body. Once a certain body part was exposed and a diagnosis had been made, the patient was generally treated on the spot. The absence of non-invasive imaging technique made the combination of diagnosis and therapy become natural.

All the changed with discovery of X-ray by Professor Roentgen in 1895. Due to this ground-breaking discovery, it was possible to visualize the internal body of a living person without any surgery. The first application of X-ray was to visualize bone fractures. After that, many other techniques of imaging have been discovered and the possible applications of the technique have grown in leaps and bounds.

Anatomies that are studied may be rigid like bone, deformable like muscle, static like skull, dynamic like heart joints or conceptual like an activity regions in PET, SPECT and functional MR imaging. A typical imaging sequence requires the patient to be exposed to the imaging equipment, sometimes with contrast enhancing agents (MRA) or markers (CT). The area of Medical Imaging technology is quite broad, with the following physical properties exploited in order to obtain an image.

2.10 MatLab

2.10.1 Overview

MatLab is a high performance language for technical computing. It integrates computation, visualization and programming in a user-friendly environment where problems and solutions are expressed is familiar mathematical notation. Typical uses of MatLab include [12]:-

- Math and computation
- Algorithm development
- Modeling, simulation and prototyping
- Data analysis, exploration and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building

MatLab is an interactive system whose basic data element is an array that does not require dimensioning. Many technical computing problems, especially those involving matrix and vector formulations can be solved in a fraction of the time it would take to write a program in a language such as C or Fortran [12].

The name MatLab stands for Matrix Laboratory. In the university environment it is a standard instructional tool for introductory and advanced courses in mathematics, engineering and science. In the industry, it is used for high-productivity research, development and analysis [12].

MatLab also has application specific solutions called toolboxes. Toolboxes are comprehensive collection of MatLab functions (M-files) that extend the MatLab environment to solve particular classes of problems. Areas in which toolboxes are available include signal processing, control systems, neural networks, fuzzy logic, wavelets, simulation and others [12].

2.10.2 MatLab and other platforms

MatLab allows interaction with data and programs external to its environment. It provides an Application Program Interface (API) to support these external interfaces. The functions supported by the API include [14]:-

- Calling C or Fortran programs from MatLab.
- Importing and exporting data to and from the MatLab environment.
- Establishing client/server relationships between MatLab and other software programs.

2.10.3 The MatLab array

The MatLab language works with only a single object type: array. All MatLab variables including scalars, vectors, matrices, strings, cell arrays, structures and objects are stored as arrays.

MatLab data types include [14]:-

- Complex double-precision matrices

- These matrices are of type double and have dimension of m-by-n, where m is the number of rows and n is the number of columns. The data is stored as two vectors of double-precision numbers – one containing real data and the other imaginary data.

- Numeric matrices

- These are single-precision, floating-print, and 8-, 16-, and 32-bit integers, both signed and unsigned. The data is stored in two vectors in the same manner as double-precision matrices.

- Strings

- Strings in MatLab are of type char, and are stored just as unsigned 16-bit integers are, except that no imaginary data component exists. Each character in the string is stored as 16-bit ASCII Unicode.

- Cell arrays

- Cell arrays are a collection of arrays, where each array is referred to as a cell. This allows arrays of different types to be stored together. Each cell can be of any supported data type, even another cell array.

- Multi-dimensional arrays

- MatLab arrays of any type can be multi-dimensional. A vector of integers is stored where each element is the size of the corresponding dimension. The storage of the data is the same as matrices.

- Logical arrays

- Any noncomplex numeric or sparse array can be flagged as logical. The storage for a logical array is the same as the storage for a non-logical array.

2.10.4 MatLab graphics

MatLab has graphics features for visualizing data and preparing presentation graphics. It has routines for building 2D and 3D graphic structures such as line plots, contour plots, mesh and surface plots, and animation. In addition to this colour, shading, axis labelling and general appearances can be controlled. Lighting effects, patches and control of aspect ratio and display size enhance data output in MatLab.

2.11 Conclusion

The traditional technique of medical image visualisation, is by using 2D MR slices. Today, medical practitioners have realised the need for 3D viewing and its contribution to medical treatment. However, building 3D images using 2D MR slices is not accurate and results in a rough surface. Alignment of individual 2D slices creates an incomplete visualisation model. Also, various interpolation techniques have to be used to create intermediate slices. Computing time becomes the cost of using this method.

Visualisation models can also be created artificially. Wax models are created by skilled craftsmen, but these are time consuming and expensive. These are also not flexible if cuts need to be obtained to view the interior of the model. In surgery planning, interactive tools are necessary to access the interior of the volume models. For therapy planning and for diagnosis, fast efficient tools that can produce a volume image rendered with a surface and lighting for realistic viewing, and allows object slicing are needed.

MR imaging enables the availability of high-resolution image modality. MRI also enables voxel acquisition, which avoids the loss of useful information using sophisticated computer technology and algorithms for image processing and computer graphics. It is possible, to obtain 'life-like' 3D images on the computer screen. These images can be interactively manipulated and rendered to provide important information for the doctor.

Hence this project will be using the computer technology know how of image processing algorithms to develop an interactive tool which will be useful for the doctor.

Many problems are encountered in the field of volume visualisation. Some of these problems themselves have branched into new areas of research. These include:-

i) The transmission speed should be very high in order to make it interactive.

ii) High Memory Requirement.

iii) Volume Visualisation System has to be such that it unites numerous visualisation methods.

iv) Reconstruction from scattered image.

v) Visualisation from complex data sets.

vi) Image intensity based measurements.

vii) Aspects of colour and opacity of voxels is not yet an automated process.

viii) Merging information from multiple modalities.

ix) Environment should be known in advance.

x) The user is to be given the flexibility to view the image the way he wishes.

The process of determining what is to be viewable as a surface and what is not to be viewable, along with deciding on aspects of colour and opacity of voxels, is not yet an automated process. At present, a user must observe the 3D data and assign these attributes in an iterative process that requires multiple renderings of the image until the user is satisfied. There is no algorithm for processing the data and deciding what it is and therefore how it is to be represented. Thus the environment must be known in advance.

Chapter 3
Methodology

CHAPTER 3 – METHODOLOGY

3.1 Introduction

Software Engineering process in a set of steps that include method, tool and procedure. Set of this step refer to Software Engineering Paradigm or Software Development Life Cycle (SDLC) model. This paradigm is choose base on project characteristic, application, tool and procedure that is used.

Paradigm or model for system development that is recognizing as methodology consist of various form that have it's own advantage and disadvantage. Then, each model have the same generic phase like definition, development and maintenance phase.

In general, methodology or manner for perform anything consist of various specific objective in system development like:

1. Get exact system requirement
2. Give the systematic manner to develop system and then the system expand will be able to be known along the development process.
3. Produce the system that can give good documentation and easy to managing.
4. Identified any modify that needed in the system in the system development life cycle.
5. Produce system that can used in any situation required (high advantage).
6. Generate the same understanding in activity, source and restriction.
7. Try to find non-consistence and redundancy that happen in the development process.

The models that will discuss in this title is representative set of steps that consist phases in system development. The discussion is important to identified the strength and the weakness along the phase. Methodology that is choose must be appropriate and exact to help in this project system development.

3.2 Methodology Discussion and Analysis

3.2.1 Waterfall Model

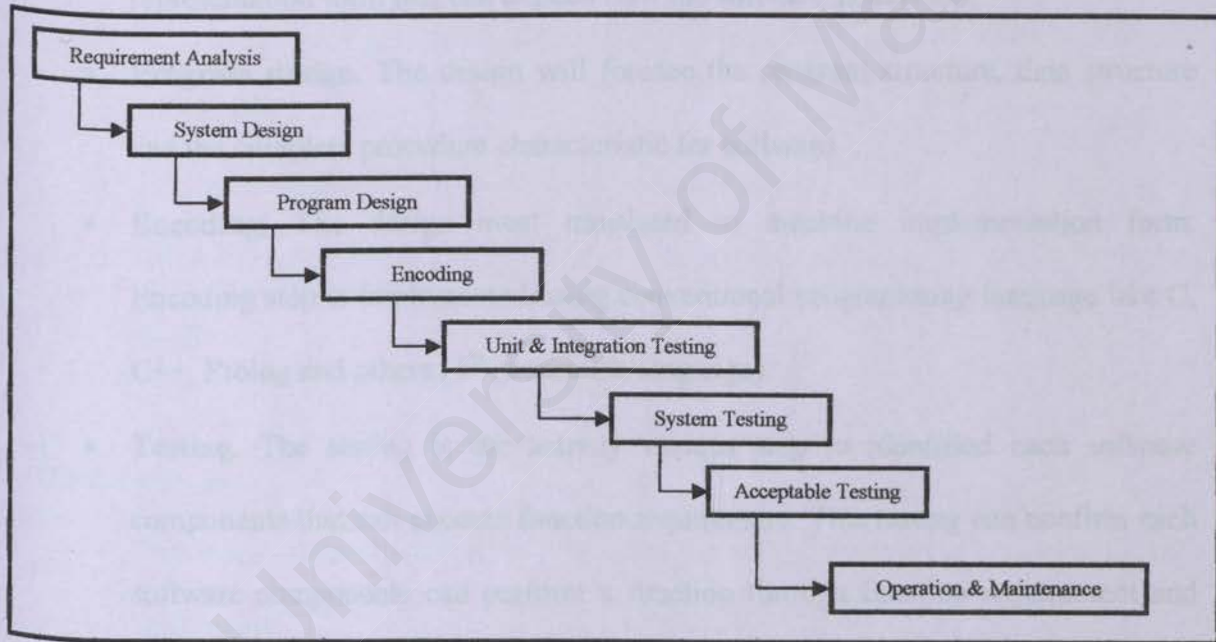


Figure 3.1 : Waterfall Model

System development through this model is the easy and simple way. Like the figure above, development process must complete before do the phase after that. All the requirement that is needed by the user, analysis for consistence and the documentation of the document that is needed and then the developer will execute system design activity. This model will make the developer easy to see what happen along the system development process.

Systems is developed through the version. The version that complete will provide to user for valuation. Then, the system will maintenance until the system ready to send to the user completely. Below is the main activity in Waterfall model:

- **Analysis.** Collect the requirement information to identified software function and performance.
- **System design.** The requirement that is collected will translated to system representation form that can explain how the software is develop.
- **Program design.** The design will foresee the program structure, data structure and the complete procedure characteristic for software.
- **Encoding**. The design must translated to machine implementation form. Encoding step is implemented using conventional programming language like C, C++, Prolog and others (4th generation language).
- **Testing.** The testing is the activity various step to identified each software components that can execute function requirement. This testing can confirm each software components can perform a function through function requirement and authenticate the system full fill all the user requirements. The software that is developed will assessed and tested to make sure it complete the specification that is defined. Interactive process or repetition will happen to delicate the software that is developed until to the good level that satisfied the user and system developer.

- **Maintenance.** The maintenance activity is to improve the each activity steps in software system. This improving is needed for repairing all errors find in software that is developed and to accommodate with the internal environment changed (e.g new hardware and operation system), or obtainable the function increasing or customer performance.

3.2.1.1 The advantages and disadvantages of waterfall model

Advantages:

- ❖ Easy to explain to customer that not usual to software development.
- ❖ This model can give software developer high level view at current software development.
- ❖ The other models is the modify from waterfall model.
- ❖ All R&D is perform before encoding is started, produce the quality program design.

Disadvantages:

- ❖ This model doesn't view how to produce the coding, except the software is really understand.
- ❖ This model doesn't give a guidance to handle any changing that happen to product or activity.
- ❖ Fail to assume the software as a problem solving activity – waterfall model is produce from hardware development.
- ❖ A phase must ready before the next phase.

3.2.2 Spiral Model

This model concentrate to decrease the risk in system development. Below is the risks that maybe happen in the system along system development process through this model.

1. The system maybe not complete user requirement.
2. The system not available with the standard quality.
3. The system development cost abundant from the allotment cost.
4. The time for system development is more than the allotment time.
5. An experts that involve in this system development leave out the project before it is complete.
6. The same development of the product but better than the current development project. This may give the project bad viewed and not update.

This model make product quality that is produced is important and try to decrease the risk along the system development. The decreasing of the risk factor can decrease the cost and time too especially in testing phase. The specific analysis too can make the maintenance phase easy and give alternatives in problem solving along the product or system development.

Even though, this model need a cooperation from the user and system developer to identified the risk and the step to solve the problems. So this model only available for internal system development which system developer and user take a part in the same organization. Cooperation for stakeholder in different organization will get a lot of problems which involve the contract and implication that doesn't expected. Beside, an exact risk analysis is not easy to do, it need a long time to deliberate and solve. So it is not something that equivalent and important because it is a small system development compare to the big system development.

3.2.3 Waterfall Model with Prototype

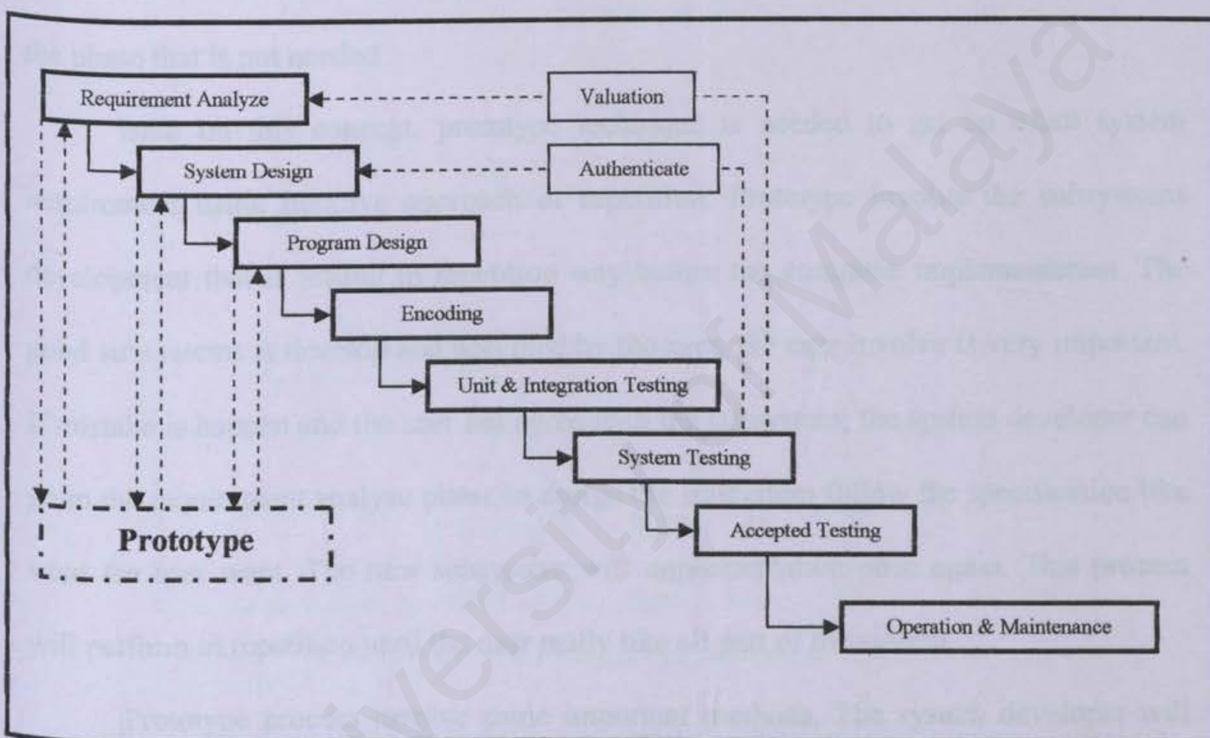


Figure 3.2 : Waterfall Model with Prototype

Waterfall Model was develop by Royce in 1970. This model need system developer to analyze the requirement first in the development. System requirement is determined, identified and checked conscientious and the system is documentation. After the specification is evaluate by the user, the next phase is determined.

This model allow the interaction and repetition in system development process. The system developer can go back to the previous phase if the system need a correction in system development. An example, in user interface design phase, a mistake in specification maybe need the system developer go back to the requirement analyze phase.

In Software Engineering, the concept or hypothesis explained if the mistake cannot identified, the cost is needed to repair the mistake is higher. That is important to identified and authenticate each phase in a good environment to avoid the repetition of the phase that is not needed.

Base on this concept, prototype technique is needed to get an exact system requirement using iterative approach or repetition. Prototype involve the subsystems development that is testing in repetition way before the complete implementation. The good subsystems is develop and accepted by the user, the user involve is very important. If mistake is happen and the user not agree with the subsystem, the system developer can go to the requirement analyze phase to design the subsystem follow the specification like what the user want. The new subsystem will implementation once again. This process will perform in repetition until the user really like all part of the system.

Prototype process involve some important methods. The system developer will design the system in a short time. This method not take a long time because only the small aspect will discuss (because it is a small system component). After that, the prototype will implement to see how the system work. The user can take part along the process to to give an interaction to the prototype units that is developed. The system developer will think over the suggestion from the user to make a change to the unit. Any change will involve prototype design method until the user satisfied with the system that is developed.

3.2.3.1 Prototype Methods

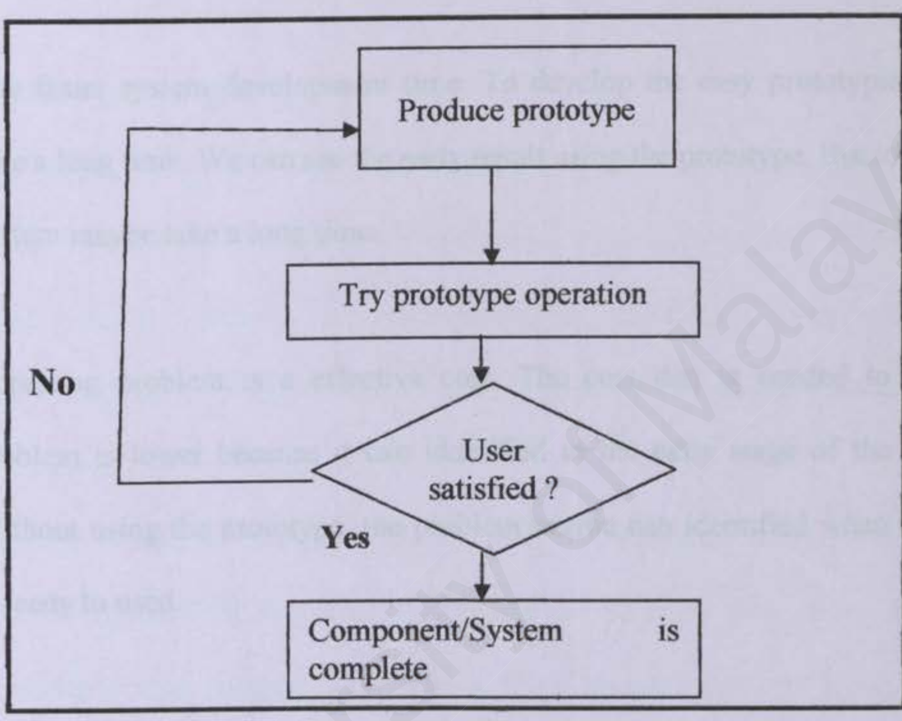


Figure 3.3 : Prototype execution

3.2.3.2 Advantages and Disadvantages of the Prototype

Prototype Advantages

1. The high commitment from the user and the good input along the system development process. One of the main objective in prototyping is design the

system that can make the user satisfied with the system. Through this method, user give an attention to the system design and the components that is developed. At the checking process, user will give an interaction to the system. Hereby, the system development objective become easy because the user give a clear guideline along the system development.

2. The faster system development time. To develop the easy prototyping, it's not take a long time. We can see the early result using the prototype. But to see all the system maybe take a long time.

3. Repairing problem is a effective cost. The cost that is needed to repair the problem is lower because it can identified in the early stage of the life cycle. Without using the prototype, the problem maybe can identified when the system is ready to used.

Prototype Disadvantages

1. Need a high commitment from the user. The problem is when user not have a time to involve in system development process. It will effect the prototype steps and the cause is it can be completely in the system development time.

2. The activities to produce the prototype maybe give to the system developer scope that not in the planning and expected. User always need a good system and the interaction from the user maybe not available with the system scope and it will

produce a big system. It will make the system become non-effective, take a long time to complete the system, and maybe it can't used. Although, a good management along the system development life cycle can conduce to deter the problem.

3.3 Analysis and Synthesis

The methodology that has been discussed include of three models. Software Development Life Cycle and project development phases include of three important phases like system analyze and requirement specification, system design and implementation. Hereby in discussion about the good and available methodology, we must at all aspects.

The first model is Waterfall Model, it is not available because if something happen like changing to the function requirement and all types of repairing the system, we can't make a change because the system that is developed not have iteration process and the development is neglected. System development process take a long time to get the objective. The system need an effective interaction with the user and discuss in all aspects that relevance. The used of this model make a project objective difficult to get the success.

Spiral Model have an own objective, it want to decrease the risk in product or system development. Although it is an effective and is used to decrease the risk that involve in the system development, but it is not available to develop a small project. The project scope in Human Heart Modeling is small and the conscientious experiment to the risk is assumed not available. Time is one of the important factor in this project. The risk analyze is not available because it take a long time to complete the system development.

The last model that give an attention to user satisfied and interactive is assumed available for Human Heart Modeling development motive is a Waterfall Model with Prototype. The Waterfall Model with Prototype use user factor-system and support insane aspects in the system development. The example is from the use interface design sight, system development is not only need to develop the interface to the user, but it need to make sure user can take and like the system. To get the interface that can make the user like it, system developer must make an experiments to Insane Engineering. The main cause why the model is choose because the time to development the system that is given is very short.

3.4 The Specific Focus To Each Phases Base on Waterfall Model with Prototype

Phase 1: Requirement Analysis

In this phase, the experiment and analysis to the current system is executed to get a clear understanding to the system and to identified the strength and the weakness of the current system. Although, it can help to search and identified the other system requirement to produce an efficient system and better than the current system. The other various techniques to achieve the motive inclusive the study of the current document, make an interview, use a question and ask to the relevance person about the system. This phase should help the system developer from a knowledge sight to the function requirement and data. The system developer must know the process, data flow and input-output of the system.

The techniques like Data Flow Diagram(DFD), Entity Relationship Diagram(ERD), Structure Diagram and State Transition Diagram(STD) maybe can use to understand the system behaviour from the graphic way.

This phase must get the user requirement too that is assumed important to information system development like user interface (e.g menu, windows) and the size of the human heart. In this phase too, the system developer must identified both function requirement and non-function requirement. It is important to make sure a success in system development. A mistake to identified the function requirement and non-function requirement not only cause the system is rejected by the user, but it can give a big loss.

Phase 2: System Design

Using the information that we get in the analysis phase, the system that is develop must design the system with the discussion of addenda requirement and any changing to the current system that is needed. In this phase, all the sub-information that be able to use will combined to design the real system.

The design include the function that can executed by system including user interface design. The techniques like Data Flow Diagram (DFD) and Entity Relation Diagram (ERD) that is used in the first phase, can used too in system design phase to get the clear understand from all sight in system design.

System design must be a communication document to the user. Although it need to be easy to get an available interaction. To get an effective design and can used by the user, an approach that will use is Human Computer Interactive(HCI) approach.

Phase 3: Implementation

Implementation phase including the encoding, testing, system documentation and training to the user and system administrator.

Encoding

The process specification is to produce a code using an available system programming language (e.g Java, MatLab and Linux) to make the maintenance become easy when the system is developed, the programming that is developed must has a program module that has a good structure.

Testing

The system developer must target a zero error in the system. The reason of this process is to repair the mistake in the system like logic and system accuracy. A good testing will minimum the number of the mistake before sent to the user. This process is important to increase the system quality.

The testing include levels like:

1) Modules or unit testing in detach way. All the error that identified will repair in a short time.

2) An effective testing is involve the modules to test how the system work and didn't have any error in the future.
3) A function testing is to make sure the system can used like what the user want and need.
4) An acceptance testing is done by the user before they receive the system in formal way.

Assessment

System assessment is done after the system is operate in period three to six month. It is done to make sure the user have a skilful using the system and to make sure the system is stable. The process is important to know the system really get the project objective.

Phase 4: Maintenance

This phase is important to make sure the system operates in dynamic with it's own environment. This phase is executed after the system is completely done and has been given to the user.

Chapter 4
System Analysis

CHAPTER 4 - SYSTEM ANALYSIS

4.1 Introduction

Like that have mentioned before, system analysis phase is the early phase in a system development life cycle. This phase is important to get an explaining and knowledge about important aspects that need to give an attention in the system development.

System analysis activity needs a specific approach including from user sight, work analysis and another requirement specification that has been given by the organization.

This analysis is important to make sure the system can execute and support requirement and policy in the organization. For the reason, analysis process is divided to main components, it is user analyze and system requirement specification that including function requirement and non-function requirement.

4.2 System requirement specification

The requirement is a characteristics or description to see what the system can do to complete the system execution that is suggested. It's not only explaining a flow of a input and output information about the system but can explain the restriction too in system execution.

To get an exact requirement, we need a repetition of process that need involve of the user and system developer. An exact requirement is important to determine the system and the system design is to determine how the system is executed.

For the system requirement specification that discuss in this chapter is to focus to function requirement and non-function requirement.

4.2.1 Function requirement

- **Image processing**

  It processed images for human consumption. Image processing include other application like image restoration, image enhancement and image compression. *Image restoration* is the process of taking an image with some known, or estimated, degradation and restoring it to its original appearance. It will make the image that cannot seen with human sight be clear after the image has been restored. *Image enhancement* involves taking an image and improving it visually, typically by taking advantage of the human visual system's response. It will stretch the contrast of an image. *Image compression* involves reducing the typically massive amount of data needed to represent an image. It will take the data of image that is important only for human perception [7].

- **Computer vision**

  It processed images for use by a computer. Computer vision include an application like image analysis. *Image analysis* involves the examination of the image data to facilitate solving a vision problem. The image analysis process involves other application like feature extraction and pattern classification. *Feature extraction* is the process of acquiring higher-level image information like shape and colour information, while *pattern classification* is the act of taking this higher-level information and identifying objects within the image like heart [7].

4.2.2 Non-Function requirement

Other important criteria to ensure the user satisfied must give an attention. It is not only about the function that is executed by the system, but it's need a non-function requirements involved.

Other non-function requirements that is must follow by the Human Heart Modeling is:-

- **Available to maintenance**

  The system is developed using an approach of a module that divide the system to a small modules. Through this modularizing techniques, each components have input, output and the clear environment about the system. It will increase an understanding of the system execution and make the maintenance of the system become easy when the system is ready.

- **Reliability**

  The system must able to give an output like what the users want when using the system. A detection of error and give a message when the error is detected must be implemented for this reason. The testing is needed to detect any weakness along the system development.

- **Efficient and correctness**

  The system can do what the user want when it is needed although it has been used all the time and it can use without any problem. The speed of interaction system too being an important issue in aspect of using system. To ensure the efficient of the system, another system like data processing and data stored need to discuss because processing operation need and take a long time.

- **Availability**

  The user need to understand the system, easy to use and accepted by the user. The system must be able to learn by the user in a short time although they use the system for the first time. The system must have a guideline how to use the system.

- **Easy to understand**

  How the system work must be able to understand by the user. Any changing can do in the system without need an involving from the other part of the system.

4.3 Hardware and Software Requirements

Hardware

Central Processing Unit	: Pentium 4 2.0 Ghz
Memory space HDD	: 40.0 Ghz
Random Access Memory	: 256 DDRAM
Other requirement	: CD-ROM, VGA and sound system

Software

Operation system	: Windows XP
Programming Language	: MatLab 6.5, 3D StudioMax

Chapter 5
System Design

CHAPTER 5 – SYSTEM DESIGN

5.1 Overview

The 2D slices are first processed to obtain 3D data. The surface of the object is then rendered using the isosurface algorithm. A lighting model is also implemented to display the object. Next, it is projected on the screen in a 3D view. The user can choose the plane in which to slice the object, thereby revealing the internal parts. In this project, the data have been searched and put in the program to make it faster to complete the project during the development time that has been given.

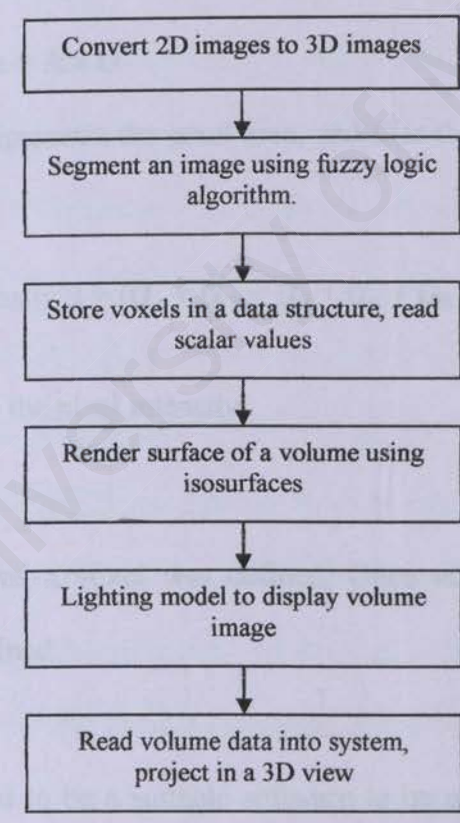


Figure 5.1 Overview of project processes

5.2 Reading of the 2D images files

2D slices had to be processed to obtain 3D volume images. As mentioned 2D MRI slices are available in the ACR format. These files have to be converted to the MAT format to be read in and manipulated in MatLab. Once the files were converted, voxels were calculated to obtain the 3D volume.

Voxel size and intensity computation was done using the following formulas. Voxel size was calculated using formula (1). The intensity of a voxel was calculated using formula (2).

(1) Voxel Size = A x D

where A represents the pixel area, and D is the distance between adjacent slices.

(2) Voxel Intensity, $I = (\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4 + \alpha_5 + \alpha_6 + \alpha_7 + \alpha_8) / 8$

where α is the pixel intensity.

Through these calculations a voxel was defined. Once voxels had been created, 3D volume images were obtained.

MatLab was found to be a suitable software to be used in thus project. MatLab allows flexible manipulations of data through its array data structure. Various built in function can be used, and conversions from other platforms are allowed.

5.3 Using fuzzy logic algorithm to segment an images

Image segmentation has three main categories techniques, such as region growing and shrinking, clustering methods and boundary detection. The region and growing and shrinking methods use the row and column (rc)-based image space, the clustering techniques can be applied to any domain such as spatial domain, colour space or feature space, while the boundary detection methods are extensions of the edge detection techniques.

Region growing and shrinking methods segment the image into regions by operating principally in the rc-based image space. The technique that use in this method is like split and merge that referred to as state space techniques and use graph structures to represent the regions and their boundaries. It define a homogeneity test that involves defining a homogeneity measure, which may incorporate brightness, colour, texture or other application-specific information, and determining a criterion the region must meet to pass the homogeneity test. It split the image into equally sized regions, calculate the homogeneity measure for each region. If the homogeneity test is passed for a region, then a merge is attempted with its neighbors, if the criterion is not met and the region is split. It continue this process until all regions pass the homogeneity test [7].

Clustering techniques method divide the space of interest into regions by selecting the center or median along each dimension and splitting it that can be done interactively until the space is divided into the specific number of regions needed. It consider the entire image as one region and compute histograms for each component of interest (for example red, green and blue for a colour image). It apply a peak finding test to each histogram, then select the best peak and put thresholds on either side of the peak and segment the image into two regions based on this peak. It smooth the binary thresholded image so that only a single connected subregion is left. It repeat the steps for region until no new subregions can be created, that is no histograms have significant peaks [7].

Boundary detection method is performed by finding the boundaries between objects, thus indirectly defining the objects. This method is usually start by marking points that may be a part of an edge. These points are then merged into line segments, and the line segments are then merged into object boundaries. The edge detectors previously described are used to mark points of rapid change, thus indicating the possibility of an edge. These edge points represent local discontinuities in specific features such as brightness, colour or texture [7].

The idea of fuzzy sets is simple and it is to define a set of gray levels that share the property of dark picture. In classical set theory, it has to determine a threshold, example like the gray level 100 and that is mean all gray levels between 0 and 100 are element of this set (Figure 5.2a). But the darkness is a matter of degree. A fuzzy set can model the darkness degree and need two threshold gray levels 50 and 150 to define this set. All gray levels that are less than 50 are the member of the set, all gray levels that are greater than 150 are not the member of the set. The gray levels between 50 and 150 have a partial membership in the set (Figure 5.2b) [22].

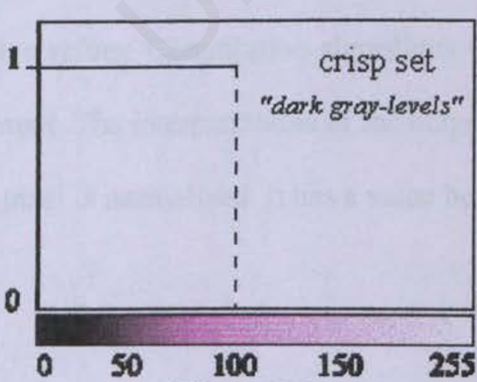


Figure 5.2a

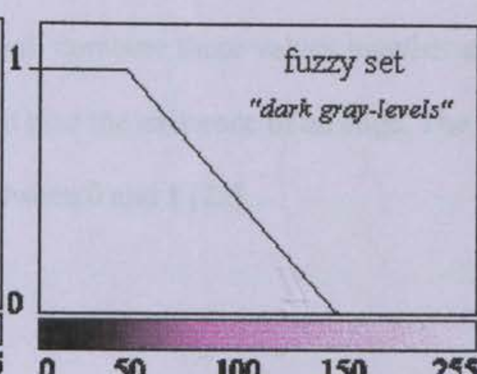


Figure 5.2b

The fuzzy set in Figure 5.3 is constructed by taking the domain of raw data and assigning corresponding fuzzy values to each member of the fuzzy set. The fuzzy set include value for true and false. The fuzzy values for bright is 0 and dark is 1. It is mean that 0 give the value of the pixel in the bright image and 1 give the value of the pixel in the dark image. The fuzzy sets are symmetric.

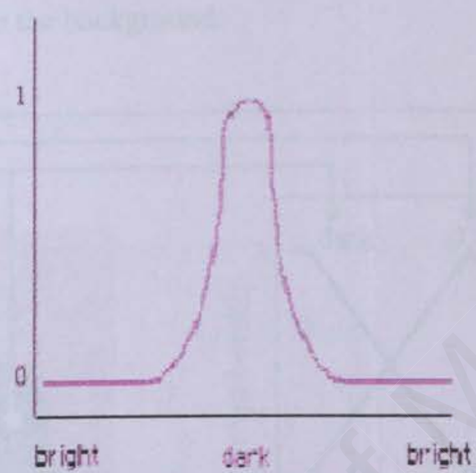


Figure 5.3 Example of fuzzy set in brightness

Convolution is the simplest solution to compute an image and the template by shifting the template into every possible position. Traditional mask convolution extracts edges by detecting local features of an edge. A mask is used as a template for an edge and the representation of the mask is arbitrary. Masks can have negative values same like positive values. Convolution algorithms will combine these values together and produce an output. The interpretations of the output give the existence of an edge. The intensity of each pixel is normalized. It has a value between 0 and 1 [22].

In Fuzzy Rule-Based Approach, the image features interpret as linguistic variables and then use fuzzy if-then rules to segment the image into different regions. A simple fuzzy segmentation rule may seem as follows:

IF the pixel is dark

AND its neighbors is also dark AND homogeneous

THEN it belongs to the background.

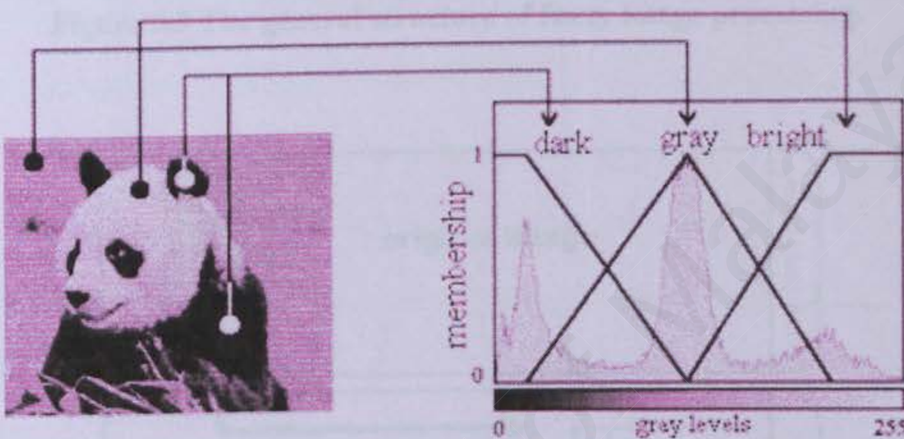


Figure 5.4 Example of brightness in image enhancement

Fuzzy image processing has three main stages like image fuzzification, membership modification and image defuzzification (Figure 5.5). The coding of image data (fuzzification) and decoding of the results (defuzzification) are used to process images with fuzzy techniques. The main step in fuzzy image processing is in the modification of membership values (Figure 5.6). After the image data are changed from gray-level plane to the membership plane (fuzzification), the suitable fuzzy techniques fuzzy clustering, fuzzy rule-based approach or fuzzy integration approach will modify the membership values [22].

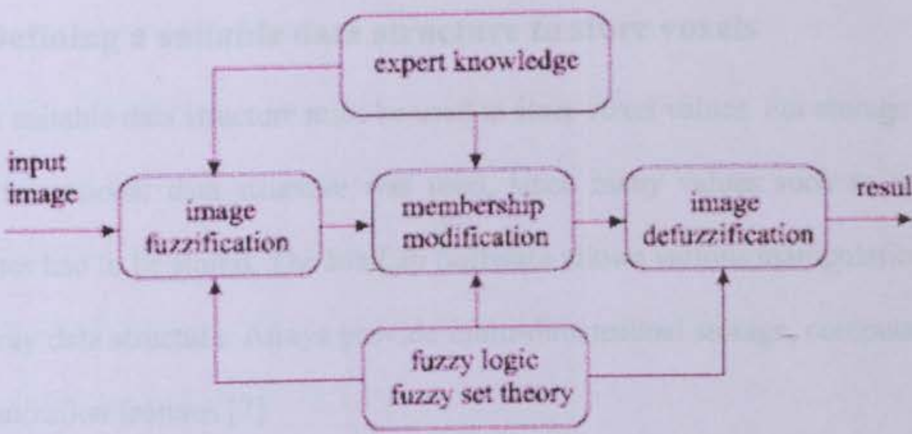


Figure 5.5 The general structure of fuzzy image processing.

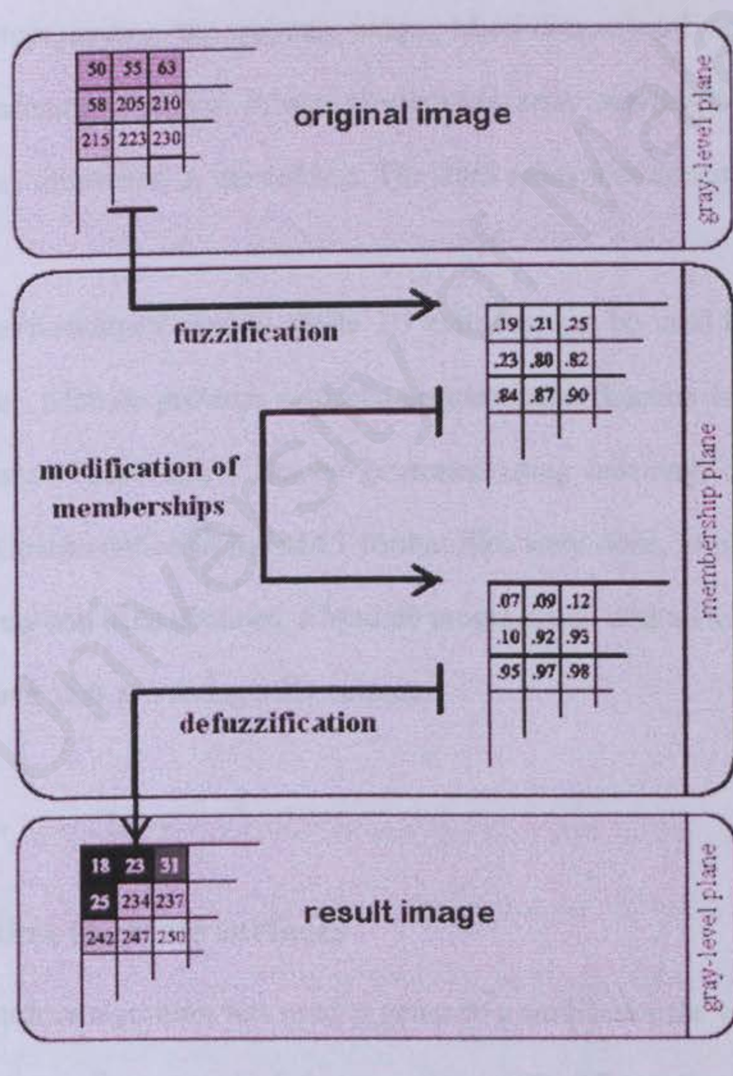


Figure 5.6 Steps of fuzzy image processing.

5.4 Defining a suitable data structure to store voxels

A suitable data structure must be used to store voxel values. For storage of voxels, a multi-dimensional data structure was used, since many values such as x, y, and z coordinates had to be stored. The MatLab Software allows various manipulation methods of the array data structure. Arrays provide multi-dimensional storage, computational and data organization features [7].

Multi-dimensional arrays in MatLab are an extension of the normal 2D matrix. A 2D matrix element can be accessed with two subscripts, one representing the row index, and the other representing the column index. Multi-dimensional arrays have three subscripts for indexing. The first subscript references array dimension 1, the row. The second references dimension 2, the column. The third references dimension 3, known as page [14].

The same techniques used to create 2D matrices, can be used to create a multi-dimensional array. MatLab provides a special concatenation function for building multi-dimensional arrays. These arrays can be generated using indexing, or using MatLab functions [14]. Concatenation of the MAT format files were done, to obtain a 3D array. When the 3D array had been obtained, a MatLab program was written to calculate voxels, as explained above, thus producing a 3D volume.

5.5 Algorithm to create surfaces

The isosurface algorithm was used to generate a surface for the volume image. An isosurface is a three dimensional plot, connecting points of constant value known as isovalues, in 3D space, to form a surface. This isosurface data is computed from the volume data. The isovalue has to be computed heuristically or through some apriori classification or segmentation algorithm. Since the scope of the project does not include classification, the isovalue was determined through the use of a built in MatLab function. The normals of the isosurface are computed using the gradient of the data. These normals, known as isonormals are important since it provide the visual appearance of lit surfaces [8][12][18]. The normals were calculated using the 'isonormals' function.

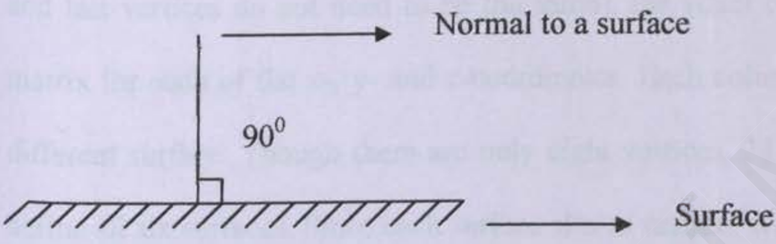


Figure 5.7 Isonormal

For the purpose of rendering the surface of the volume, the isosurface was generated as a patch. A patch is a graphics object, composed of one or more polygons defined by the coordinates of its vertices. Patches are used for modeling real-world objects such as airplanes or automobiles, or for drawing 2D or 3D polygons of arbitrary shape [12].

A patch is defined by specifying the coordinates of its vertices and some form of colour data. The colouring and lighting of the patch can be defined. Patches support a variety of colouring options that are useful for visualizing data. Once the patch has been generated, its vertex normals are recalculated in order to improve the appearance when lighting is applied. By doing this, a view of the object is set through the lighting model [12].

When an x-, y- and z-coordinates is specified, patches work by connecting points to form a single polygon. If the arguments are matrices, one polygon per column is drawn, producing a patch with multiple surfaces. The surfaces do not have to be connected and can be self intersecting.

A voxel is defined by eight vertices that form six sides. Each of the six surfaces has four vertices. Since the polygon that is generated does not need to be closed (the first and last vertices do not need to be the same), the voxel can be defined using a 4-by-6 matrix for each of the x-, y- and z-coordinates. Each column of the matrices specifies a different surface. Though there are only eight vertices, 24 vertices must be specified to define all six surfaces. Since each surface shares vertices with four other surfaces, a patch can be defined more efficiently by defining each vortex only once and the specifying the order in which to connect these vertices to form each surface [12].

Patch objects employ a colouring scheme that does not automatically generate colour data based on the value of the z-coordinate at each vortex. The colouring must be specified explicitly, otherwise the default of white surface colour and black edge colour is used. The patch colouring methods provide a means to display pictures of real-world objects with information superimposed on then through the use of colour. Each patch is bound by edges, which are line segments that connect the vertices. When patch have multiple surfaces that share vertices, some of the edges may overlap. When this happens, the edges of the most recently drawn surface overlay previously drawn edges [12].

One of the patch properties that were used is 'Edge Color', where edges cab be made invisible, of single colour, of flat colour (colour that is the result of specifying one colour per surface), and interpolated colour (colour obtained through a transition from one vertex to the next). The 'Surface Colour' property was also used to adjust surface colouring in the same way [12].

MatLab has many built in functions for modeling 3D surfaces. These functions were used to implement the above mentioned algorithm.

5.6 Lighting Model

Lighting is a technique for adding realism to a graphical scene. It does this by simulating the highlights and dark areas that occurred an object under natural lighting, for example, the directional light that comes from the sun.

Three important properties are colour, style and position. The colour property refers to the colour of the colour light cast on the object. The style property determines the distance of the light source, either infinitely far away or local, while the position property determines the direction of the light if it is an infinite light source, and the location of the light if it is a local light source [12].

Creating a light activates lighting-related properties controlling characteristics, such as the ambient light and reflectance properties of objects. Light objects cannot be seen, but their effects can be seen on any patch object present in the axes containing the light.

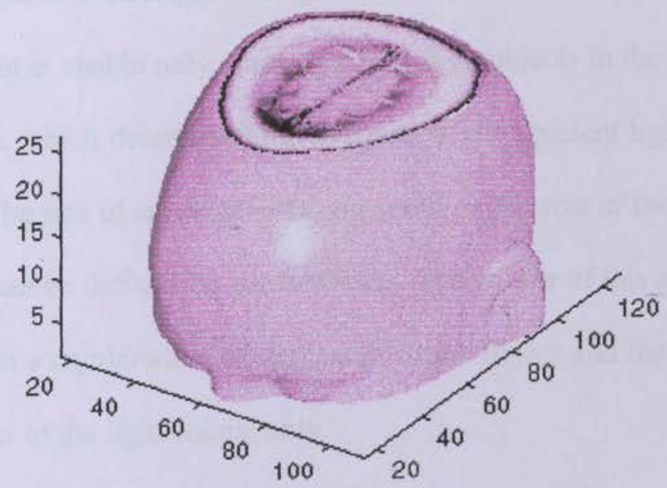


Figure 5.8 3-dimensional image lighting

In MatLab, three different algorithms for lighting calculations are supported, by setting properties of patches such as 'Face Lighting' and 'Edge Lighting'. Each algorithm produces a different effect. The Flat Lighting algorithm produces uniform colour across each of the faces of the object. This method is suitable for faceted objects. Gouraud lighting calculates the colours at the vertices and the interpolates colours across the faces, making it the most suitable method to view curved surfaces. Phong lighting, the third algorithm, interpolates the vertex normals across each face, and calculates the reflectance at each pixel. This method is also chosen for curved surfaces. It produces better results than Gouraud lighting, but it takes longer to render [12].

Patch object properties reflect light. These properties can be used in combination to produce particular results. Reflection of the light can be controlled through the amount of specular and diffuse reflection from the surface of an object, by setting the ' Specular Strength' and 'Diffuse Strength' properties [12].

Ambient light is a directionless light that shines uniformly on all objects in the scene. Ambient light is visible only when there are light objects in the axes. Properties of colour and strength, which determines the intensity of the ambient light on the particular object can be set. The size of specular highlight spots, or the size of the area where a light source originates, can be defined on patch objects. The colour of this specularly reflected light can range from a combination of the colour of the object and the colour of the light source, to the colour of the light source only.

Lighting models were used to improve the appearance of the rendered volume and sub-volume image. All the lighting properties discussed were explored and manipulated to make images more clearer and natural looking.

5.7 Volume and sub-volume visualization

Volume visualization was done after a surface had been rendered, and lighting effects implemented. The volume was projected in a 3D view through manipulation of various MatLab functions. The sub-volume was obtained by using the 'sub-volume' function in MatLab. Data ranges along the x-, y- and z-axis, corresponding to where the user would like to view the volume are read into the function. This portion of the volume is then extracted and displayed.

5.8 Graphical User Interfaces (GUI)

The GUI was developed by using the interactive Guide Editor in MatLab. Developing an interface in MatLab proved to be a challenge to the author. The GUI development tools were found to be rather unstable, causing constant craches, and non-user friendly.

However, through the implementation of a GUI, the visualization system has been made user-friendly. The user can view the volume through just the clicks of buttons. Once the volume has been rendered and viewed, the user has to enter data ranges for the x-, y- and z-axis corresponding to where he would like to view the volume. A second click of the mouse displays a rendered sub-volume. Any portion of the volume can be extracted to be viewed as a sub-volume, depending on the values entered by the user.

The user is allowed to interactively slice the volume, by first selecting a plane in which he would like to view internal regions of the volume. This displays another window. The selects a value at which he wants to see a slice and clicks on a button to view it.

Chapter 6
System Implementation

CHAPTER 6 - SYSTEM IMPLEMENTATION

6.1 Overview and Development Environment

The hardware that I use in this system is Pentium 4 2.0 GHz processor, 40.0 GHz memory space hard disk and 256 DDRAM. The software that I use in this system is MatLab (Matrix Laboratory) and the operating system is Windows XP. MatLab have a lot of demos in the software, so it makes the process to develop the system become easier. It has a guideline how to start the programming language and use it, and it is a software programming that easy to use by any person and easy to understand. In MatLab, I use fuzzy logic function that is fuzzy c-mean clustering as an A.I technique in my system and 3D visualization as a graphics toolbox to develop a 3-dimension Human Heart Modeling.

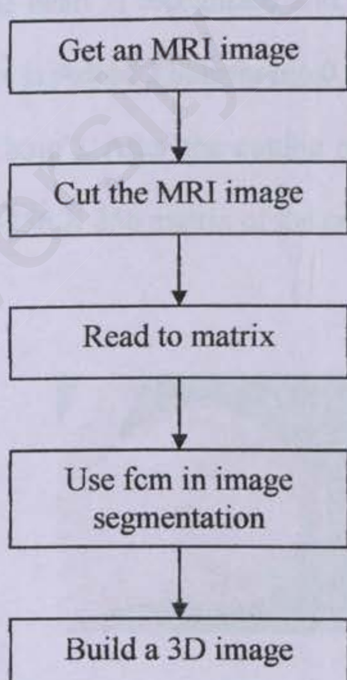


Figure 6.1 Development process

There are five steps before get the 3D image and the first one is getting an MRI image. The format of the image is saved in file '.tiff' and it shows all part of the human body.

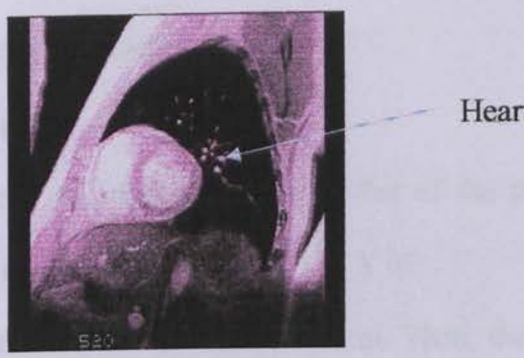


Figure 6.2 Original images before Region of Interest

The second step is cutting the MRI image and the process is called Region of Interest (ROI). The ROI of the heart is recognized and only the heart area is cut. The software I used to cut the heart is Adobe Photoshop 6.0 and the heart image is saved in file with the format bitmap ('.bmp'). After the cutting process, we can have 110 X 97 matrix image of the heart from 256 X 256 matrix of the original image.

Figure 6.3 Region of Interest of the human heart image

6.2 Reading of the 2D images files

The 2D images had to be processed to obtain 3D images. When the files were converted, voxels were calculated to obtain the 3D images.

The 2D images was read by using the function like

a = imread('jantung.bmp').

When this function is executed, the input gives output list of the matrix for the file jantung.bmp. The output gives matrix with the size of 110 X 97.

When the file is read, the matrix is saved in file matrix1.m. Then, the file matrix1.m is called from memory using function load

load matrix1.m;

In the program, the matrix.m is named by variable data

data = matrix1

6.3 Clustering process using Fuzzy c-means in image segmentation

```
m = 0;
for i = 1 : 97
    for g  = 1 : 110
        m = m + 1;
        w = data(i,g);
        b(m,1) = w;
    end
end
```

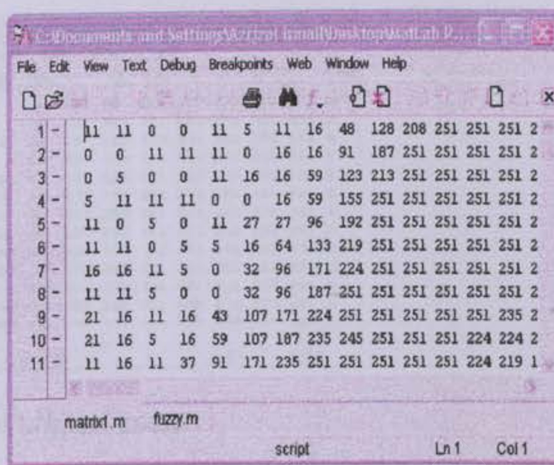
[center,u,obj_fcn] = fcm(b,4);

maxU = max(u);

Start a counter with m = 0, and then use the loop function to read all data from row 1 to row 97 and all data from column 1 to column 110. Add counter m with 1 and will add after this until all data have read. Variable w is equal to all data in column (i,g) and the data convert to one column of all data and will stored in b. That mean the size of 110 X 97 of matrix1 is convert to matrix with size 10670 X 1. When using function [center,u,obj_fcn] = fcm(b,4); 'b' is a data set to be clustered; each row is a sample data point, '4' is number of clusters, 'center' is matrix of final cluster centers where each row provides the center coordinates, 'u' is final fuzzy partition matrix (or membership function matrix) and 'obj_fcn' is values of the objective function during iterations. Function maxU = max(u) is to define the maximum value of u.

The image that is used in this program is a Magnetic Resonance Image (MRI) was build from 3-dimensional matrix of m x n x p bit of pixels. Each pixel representing a gray intensity value (p). The grey intensity value is from 1 to 64 for the MR image. If the value nearer to 64, the pixel look brighter and more white. Otherwise if the value is nearer to 1, the pixel looks darker and more black. So, the first step in implementation is to transfer the image to a matrix in size of n x n that contain a bit of pixels with a different pixel value for each others.

Original image



Matrix of original image

Figure 6.4 Convert image to matrix

And then find the data points with highest grade of membership in the cluster using this function.

index1 = find(u(1,:) == maxU);

index2 = find(u(2,:) == maxU);

index3 = find(u(3,:) == maxU);

index4 = find(u(4,:) == maxU);

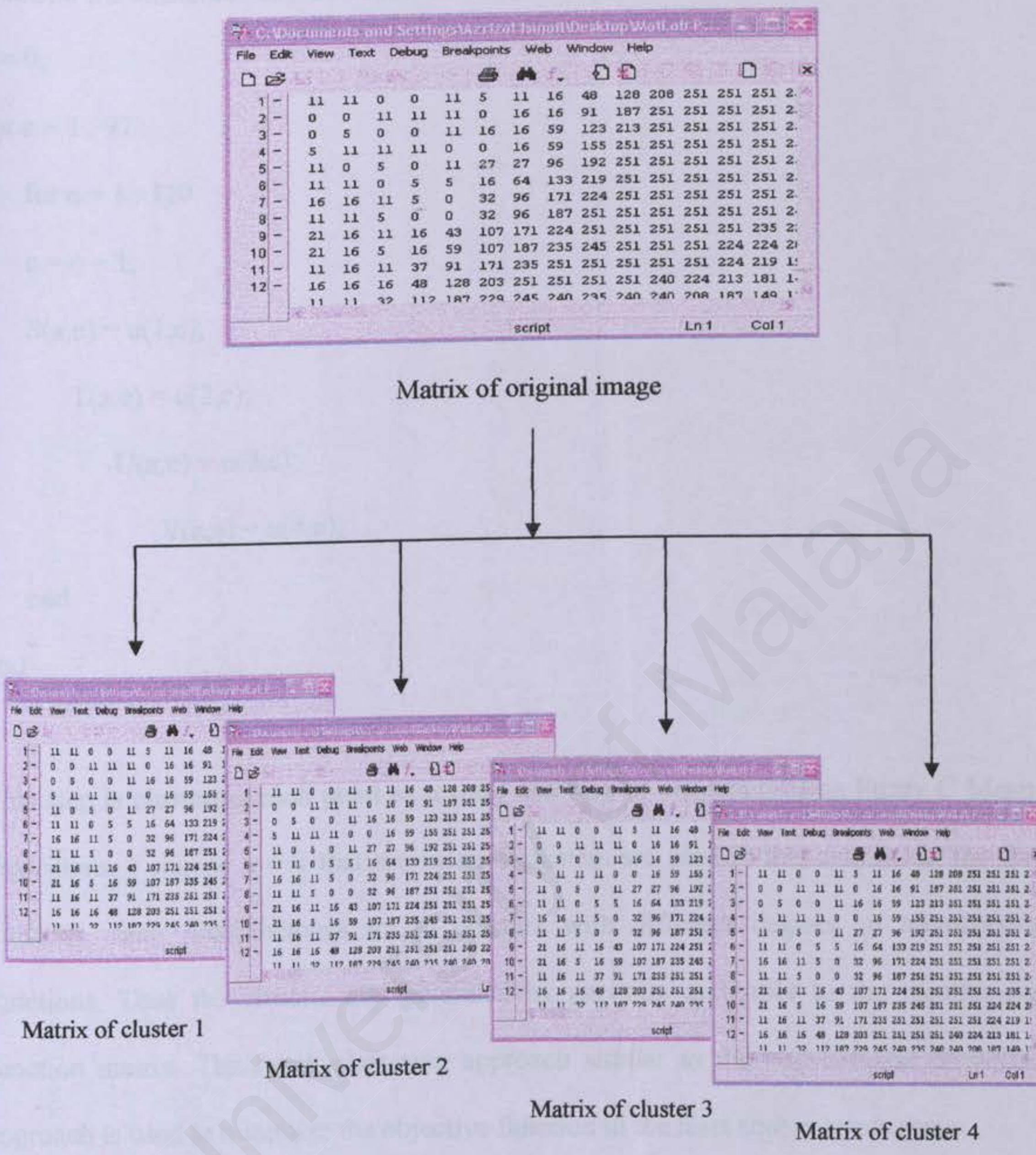


Figure 6.5 Clustering process to develop 4 clusters

Transfer the clustered matrix to show an image

```
c = 0;
for a = 1 : 97
    for e = 1 : 110
    c = c + 1;
    S(a,e) = u(1,c);
        T(a,e) = u(2,c);
            U(a,e) = u(3,c);
                V(a,e) = u(4,c);
    end
end
```

This step is clustering each pixel to several numbers of clusters n using Fuzzy C Means algorithms. I choose n = 4 that are mean 4 clusters are used in this system. In the fcm methods, each pixel belongs to all clusters with different degrees of membership functions. Thus the clusters are generated by partition and refer to the membership function matrix. The fuzzy clustering approach similar to the conventional clustering approach is used to minimize the objective function in the least square errors sense.

Shows the image of each clusters

figure, imshow(S)

figure, imshow(T)

figure, imshow(U)

figure, imshow(V)

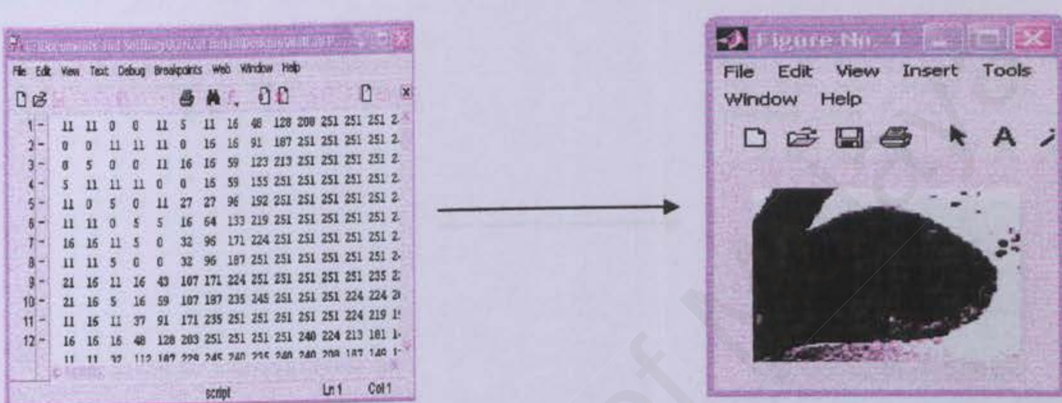


Figure 6.6(a) Image of cluster S

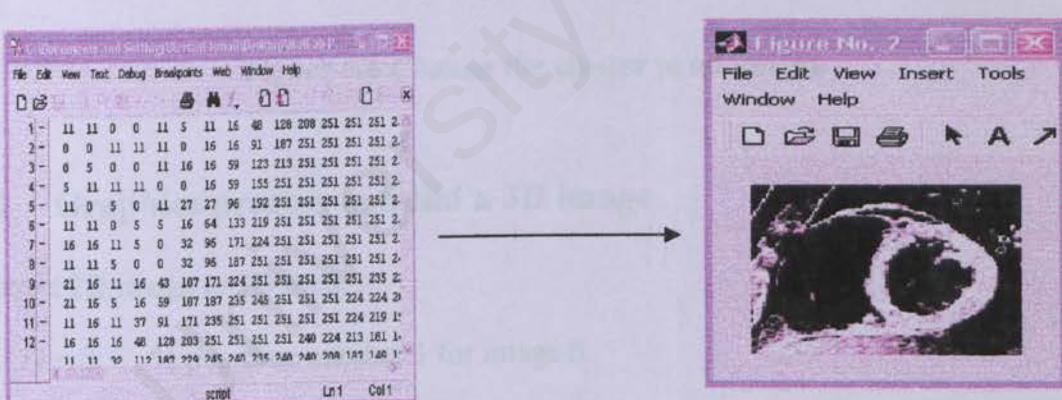


Figure 6.6(b) Image of cluster T

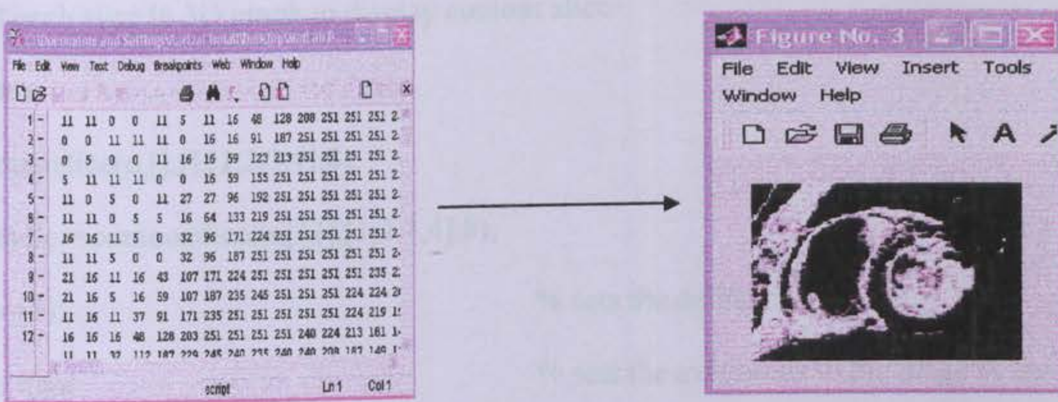


Figure 6.6(c) Image of cluster U

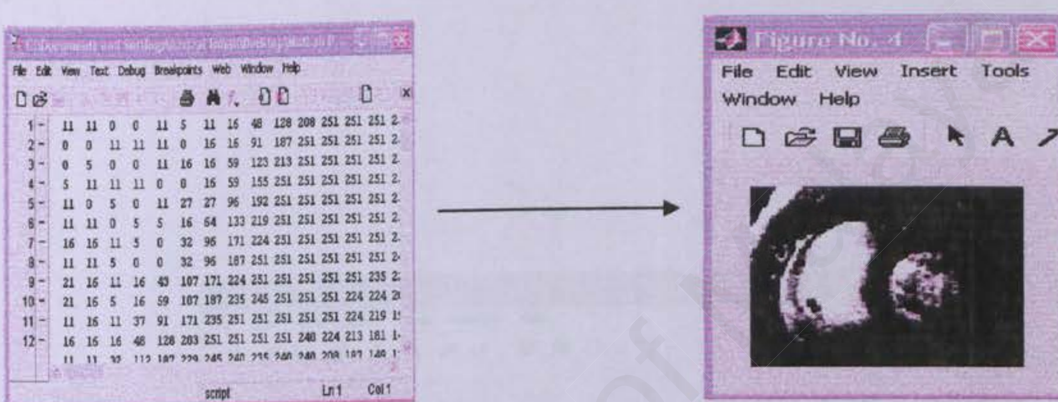


Figure 6.6(d) Image of cluster V

Figure 6.6 Change the cluster to an images

6.4 Graphics process to build a 3D image

Convert 2D image to 3D image

p(:,:,1) = S; % p is slice number 1 for image S

p(:,:,2) = T; % p is slice number 2 for image T

p(:,:,3) = U; % p is slice number 3 for image U

p(:,:,4) = V; % p is slice number 4 for image V

Plot each slice in 3D graph to display contour slice

```
figure
contourslice(p,[],[],[1,2,3,4],8);
phandle = contourslice(p,[],[],[1,2,3,4],8);
view(3);                              % sets the default 3-D view
axis tight                            % sets the axis limits to the range of the data
set(phandle,'LineWidth',2)
```

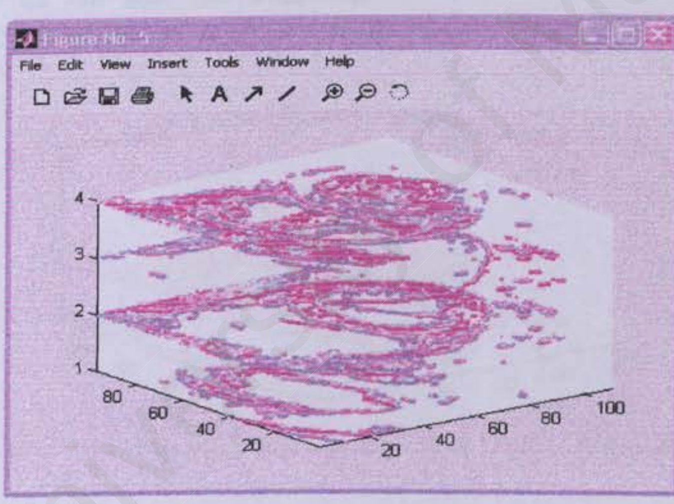


Figure 6.7 Image after the contourslice process

The input data is p and returns the smoothed data in ps, calculate the isodata display this data as a graphics object.

```
ps = smooth3(p);
hiso = patch(isosurface(ps,5),...
        'FaceColor',[1,.75,.65],...
        'EdgeColor','none');
```

Figure 6.8 Image after isosurface process

Calculate the data to display at the same isovalue (5) as the surface.

```
hcap = patch(isocaps(p,5),...
        'FaceColor','interp',...
        'EdgeColor','none');
```

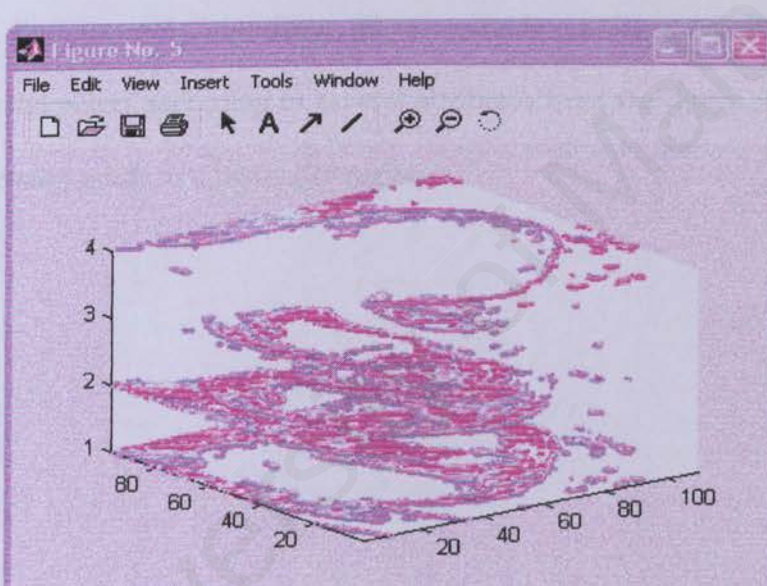


Figure 6.9 Image after isocaps process

6.5 System implementation conclusion

System implementation is important to make sure any changing that is needed managed in the right way. The effective system implementation can ensure the quality of the system. So, that is important to measure the effective of the implementation to see how far the success of the system. We can see the specified process in the system for every process that the systems execute. This is to make sure the system can operate successfully. Fuzzy c-means algorithm uses the reciprocal of distances to decide the cluster centers. The representation reflects the distance of a feature vector from the cluster center. Fuzzy c-mean algorithm, allows providing a fuzzy partition of the image by classifying the pixels according to several attributes from the image. It gives for each pixel a membership grade to a particular region.

Chapter 7
System Testing

CHAPTER 7 - SYSTEM TESTING

7.1 Unit testing

Make sure the fuzzy logic toolbox is used in the right way like the fcm (fuzzy c-means clustering) data set. Every unit is tested by check the size of the matrix at workspace in the MatLab programming. Matrix1 have size of 110 X 97, so the variables that connected to the matrix1 must have the same size of the matrix1 like variables data, S, V, U, and T.

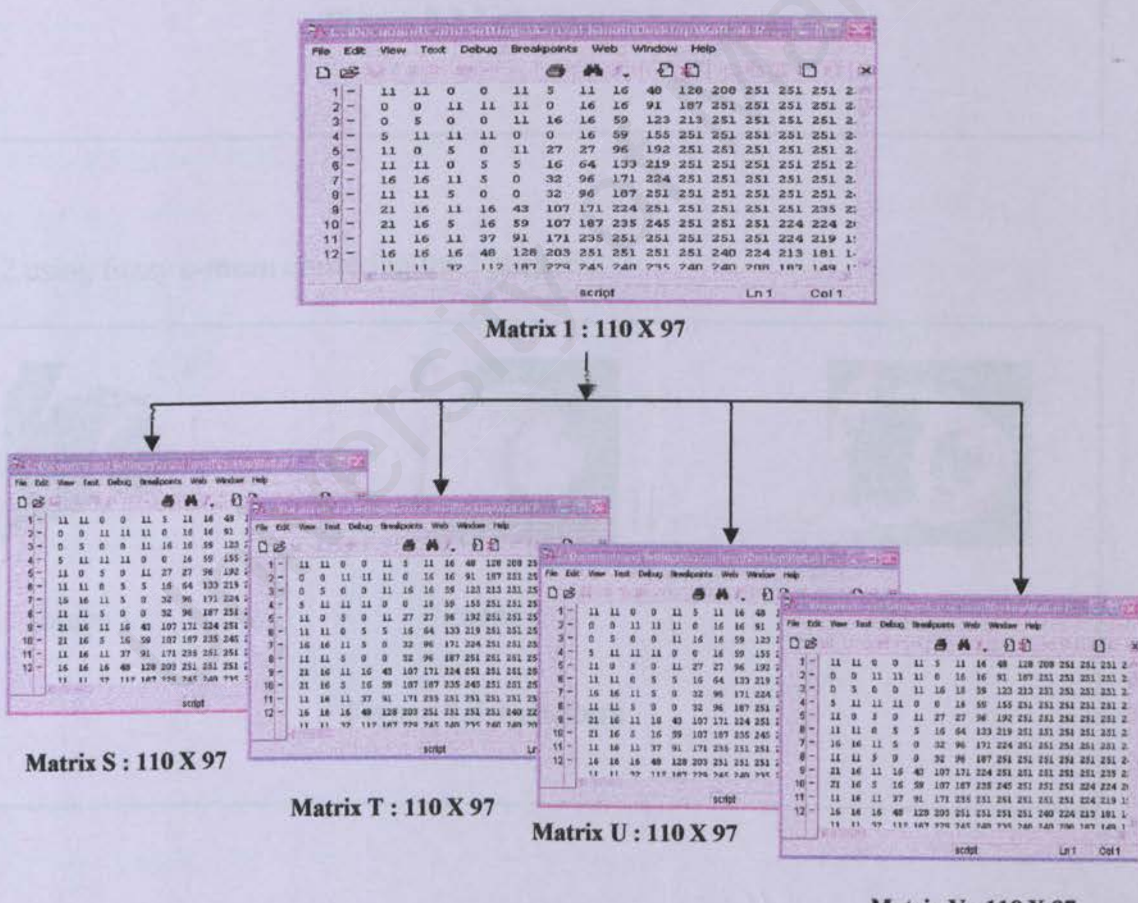


Figure 7.1 Size of every matrix

7.2 System testing

Fuzzy c-mean clustering process

For **[center,u,obj_fcn] = fcm(data,n_cluster);**

Test 1 using fuzzy c-mean clustering for 2 clusters,

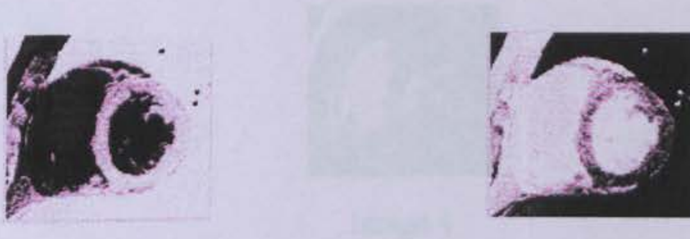


Image 1 Image 2

Figure 7.2 2-clusters

Test 2 using fuzzy c-mean clustering for 3 clusters,

Image 1 Image 2 Image 3

Figure 7.3 3-clusters

Test 3 using fuzzy c-mean clustering for 4 clusters,


Image 1


Image 2


Image 3


Image 4

Figure 7.4 4-clusters

Test 4 using fuzzy c-mean clustering for 5 clusters,


Image 1


Image 2


Image 3


Image 4


Image 5

Figure 7.5 5-clusters

Test 5 using fuzzy c-mean clustering for 6 clusters,

Figure 7.6 6-clusters

Test 6 using fuzzy c-mean clustering for 7 clusters,

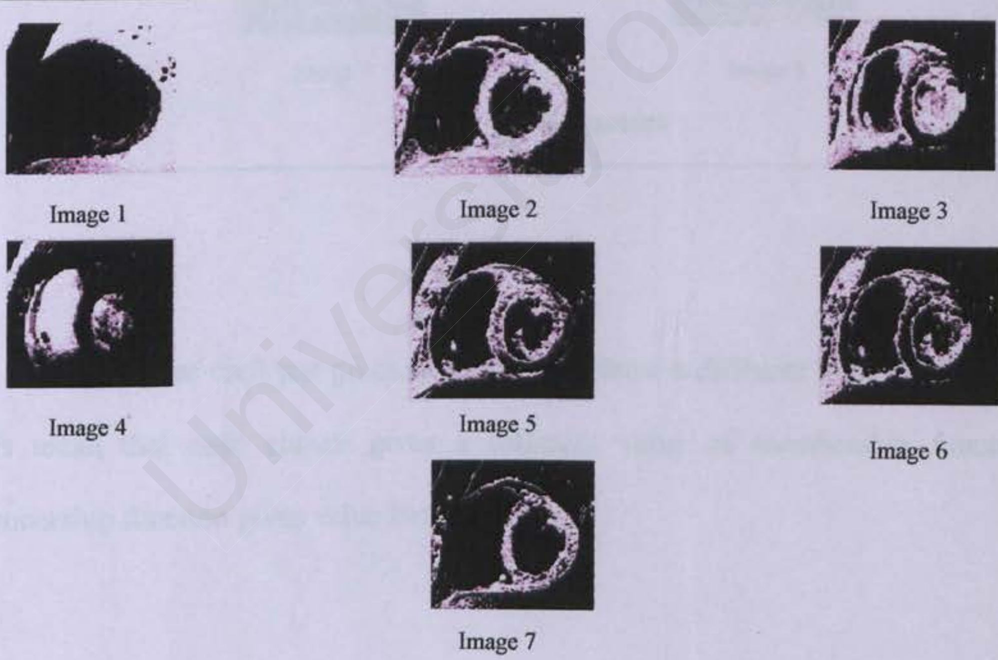


Figure 7.7 7-clusters

Test 7 using fuzzy c-mean clustering for 8 clusters,

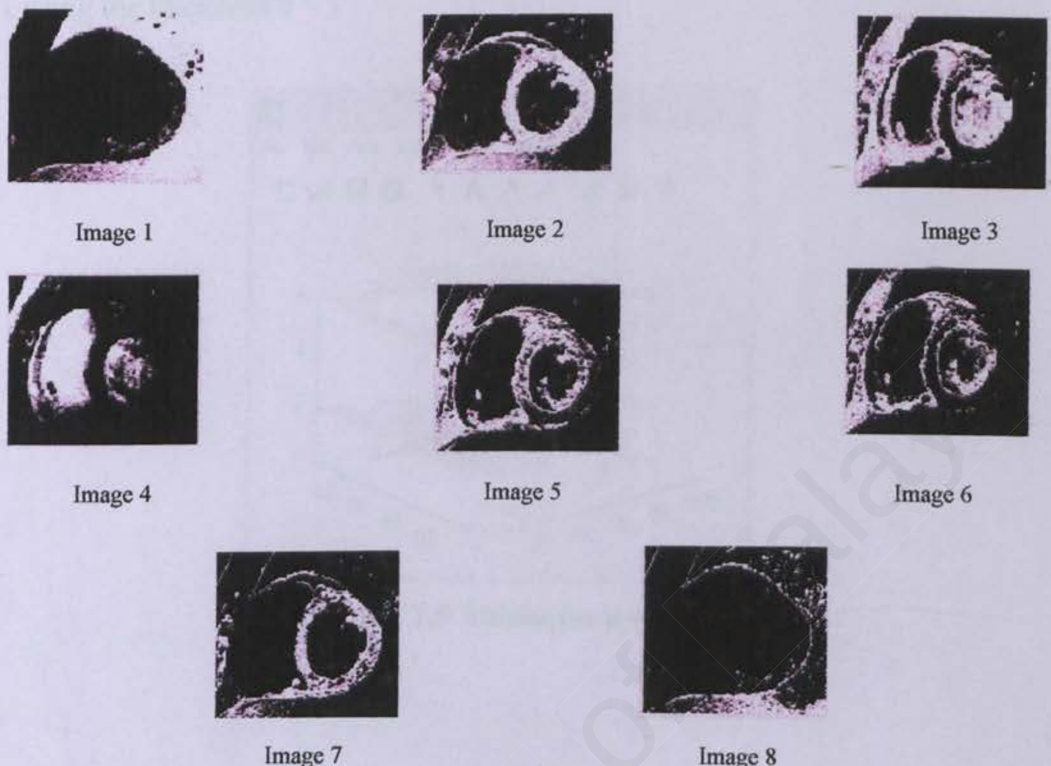


Figure 7.8 8-clusters

We can see each test gives an output that show a different images of each cluster, it is mean that each cluster gives a different value of membership function. The membership function gives value between 0 and 1.

Graphics process

For **contourslice(p,[],[],[1,2,3,4],n);**

Test 1 using the thickness n = 1

Figure 7.9 Thickness n = 1

Test 2 using the thickness n = 2

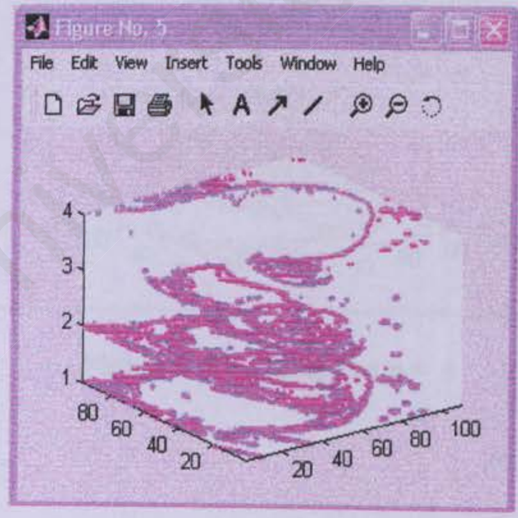


Figure 7.10 Thickness n = 2

Test 3 using the thickness n = 3

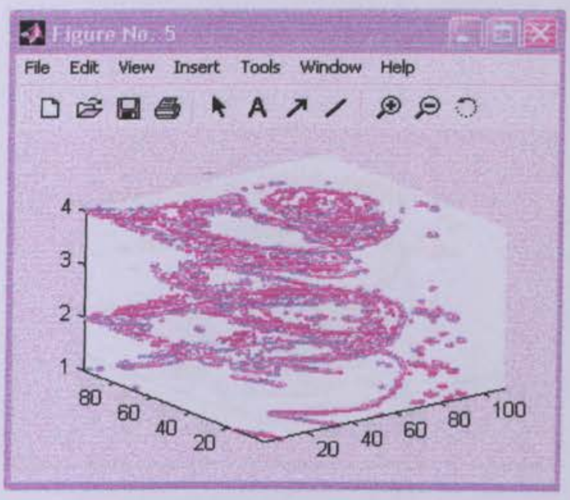


Figure 7.11 Thickness n = 3

Test 4 using the thickness n = 4

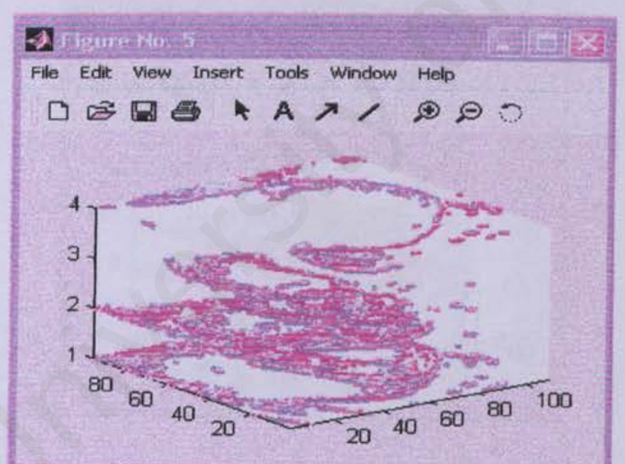


Figure 7.12 Thickness n = 4

Test 5 using the thickness n = 5

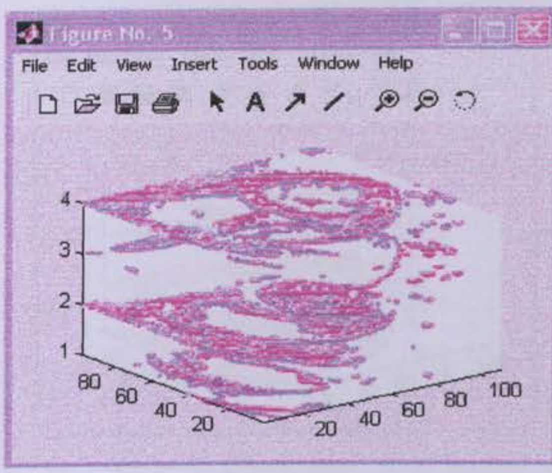


Figure 7.13 Thickness n = 5

Test 6 using the thickness n = 6

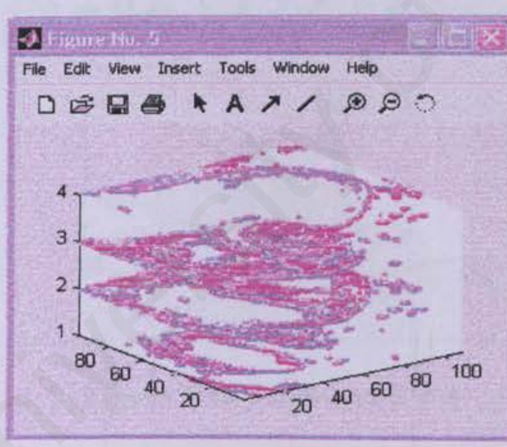


Figure 7.14 Thickness n = 6

Test 7 using the thickness n = 7

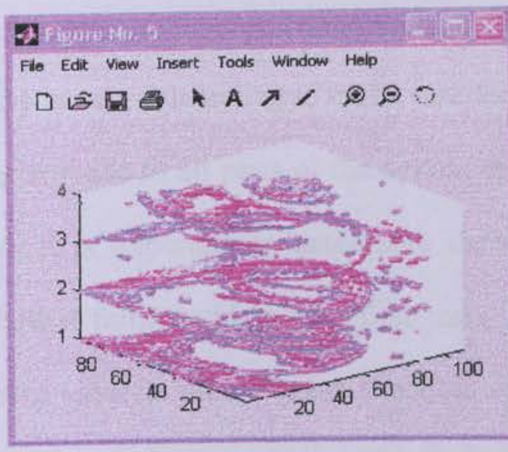


Figure 7.15 Thickness n = 7

Test 8 using the thickness n = 8

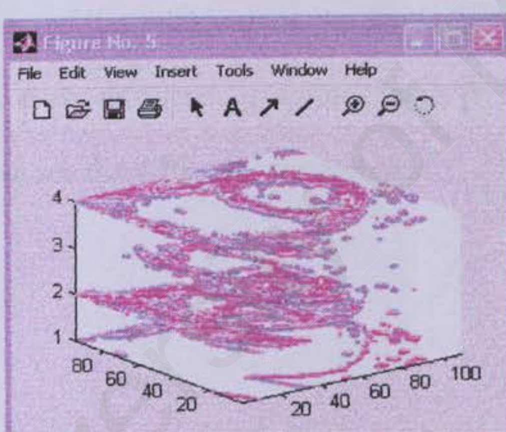


Figure 7.16 Thickness n = 8

The reason of this test is to find the value of thickness that can create the surface of the heart, the surface is to joint each slice with another (joint the slice 1, 2, 3 and 4 each other). We can see each test for thickness value give different type of thickness. If the thickness is 1, it gives a thin type of slices and so on, but when the thickness value is from 4 to 8, the thickness is look like same for each value from 4 to 8.

7.3 Testing conclusion

The testing to the system is a testing to make sure the level of system execution. In this level, the testing is made to all parts of the system to see the execution of every function in the system. It is important to make sure the objective of the system in requirement analysis phase is fulfill and this is the final test.

When a difference value is used to each function, it gives a difference type of images. We can have difference images of heart if we put the difference value of how many clusters that we want. It gives the difference intensity to each of the images.

In the isosurface process, it gives difference types of the slice form when it is plot in a 3D graph. The size of the thickness or the isosurface from thick and it become thicker and thickest for every difference isosurface value from 1 to 8. It is same too for the isocaps value, we can see the difference for each test.

Chapter 8
Discussion

CHAPTER 8 - DISCUSSION

8.1 The result of the system

The system that was developed can give an output until the graphics process. From 2D image, it was read to the system and the matrix that is get is stored in m-file. After that, that matrix is segmented using fuzzy c-mean clustering. So, the second objective of my thesis was executed (see project objective in chapter 1). Clustering techniques method divide the space of interest into regions by selecting the center or median along each dimension and splitting it that can be done interactively until the space is divided into the specific number of regions needed. It consider the entire image as one region and compute histograms for each component of interest. It apply a peak finding test to each histogram, then select the best peak and put thresholds on either side of the peak and segment the image into two regions based on this peak. It smooth the binary thresholded image so that only a single connected subregion is left. It repeat the steps for region until no new subregions can be created, that is no histograms have significant peaks. The 2D image was converted to 3D image in graphics process (see System Implementation in chapter 6) and it means the first objective of my thesis has been executed. Each images had been arrange in 3D graph to get a 3D object.

8.2 The problem of the system

The problem of my thesis is it can't create a surface that can get a 3D object. Maybe the value of surface can't be detected yet. So, the next stage that is wanted to build the 3D object and heart pumping can't be done.

8.3 Advantage and disadvantage

The advantage of this system is it can arrange the size of matrix n by n to matrix n by 1. This matrix is used for the fuzzy c-mean clustering process because the fuzzy c-mean just process the matrix for size n by 1. The disadvantage of this system is it can't make the 3D object that is human heart modeling pumping yet because it is not completely finish yet. It takes a long time to process the matrix; it takes about 18 seconds to process the matrix, so it needs a powerful hardware and more disk space to run the program to run the program in just a second. The program is not providing with any user interface yet because there some other part of the program need to be changed first for using the system.

8.4 Future research

For future research, they can continue on how to create a surface from a MRI slice and then they can put a movie function in the system to make the heart pump. Both of the parts are an important part to make the heart pumping. So after that it can be used for medical environment and will give more advantages explicitly for the medical used and generally for student used.

8.5 Conclusion

I have found the environment of the thesis very exciting, more inspirational and a lot of rewarding. This thesis allowed me to explore a difference field of science such as medical imaging, image processing and computer graphics. Human heart modeling is a 3D modeling, that is the technology of the future and it is an important tool yet to be fully exploited by the medical community. It gives great pleasure and a deep sense of satisfaction to me for having contributed in the area of 3D modeling.

Appendixs

APPENDIXS A

Human Heart Modeling Program

```
clear all
close all               %for clear all data in workspace
load matrix1.m          %call file name matrix1.m from memory
data = matrix1;         %matrix1 is named by a variable data
m = 0;                  %start a counter with m = 0
for i = 1 : 97          %read all data from row 1 to row 97
   for g = 1 : 110      %read all data from column 1 to column 110
      m = m + 1;        %add counter m with 1 and will add after this until all data is read
      w = data(i,g);    %w is equal to all data in column (i,g)
      b(m,1) = w;       %the data has been convert to one column of all data,b.
            %That mean the size of 97 X 110 of matrix1 is convert to 10670 X 1.
   end
end
[center,u,obj_fcn] = fcm(b,4);       %b is data set to be clustered; each row is a sample
                                     data point
                                     %4 is number of clusters
                                     %center is matrix of final cluster centers where each
                                     row provides the center coordinates
               %u is final fuzzy partition matrix (or membership function matrix)
               %obj_fcn is values of the objective function during iterations
```

```
maxU = max(u);                    % Define the maximum value of u

% Find the data points with highest grade of membership in cluster 1

index1 = find(u(1,:) == maxU);

index2 = find(u(2,:) == maxU);

index3 = find(u(3,:) == maxU);

index4 = find(u(4,:) == maxU);

%arrange the matrix of each cluster and change it to an images


c = 0;

for a = 1 : 97

  for e = 1 : 110

    c = c + 1;

    S(a,e) = u(1,c);

      T(a,e) = u(2,c);

        U(a,e) = u(3,c);

          V(a,e) = u(4,c);

  end

end
```

```
figure, imshow(S)

figure, imshow(T)

figure, imshow(U)

figure, imshow(V)


p(:,:,1) = S; % p is slice number 1 for image S

p(:,:,2) = T; % p is slice number 2 for image T

p(:,:,3) = U; % p is slice number 3 for image U

p(:,:,4) = V; % p is slice number 4 for image V


% plot each slice in 3D graph to display contour slice


figure
contourslice(p,[],[],[1,2,3,4],8);
phandle = contourslice(p,[],[],[1,2,3,4],8);
view(3); % sets the default 3-D view, AZ = -37.5, EL = 30
axis tight % sets the axis limits to the range of the data
set(phandle,'LineWidth',2)
```

```
% The input data is p and returns the smoothed data in ps,calculate the

% isodata and display this data as a graphics object.


ps = smooth3(p);

hiso = patch(isosurface(ps,5),...

   'FaceColor',[1,.75,.65],...

   'EdgeColor','none');


% calculate the data to displayed at the same isovalue (5) as the surface.


hcap = patch(isocaps(p,5),...

   'FaceColor','interp',...

   'EdgeColor','none');
```

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